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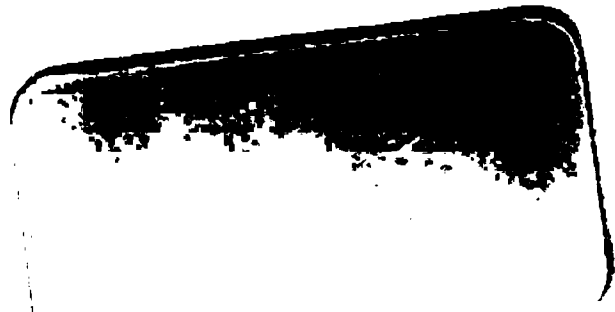
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THE
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ANATOMY AND PHYSIOLOGY
NORMAL AND PATHOLOGICAL,
HUMAN AND COMPARATIVE.

CONDUCTED BY

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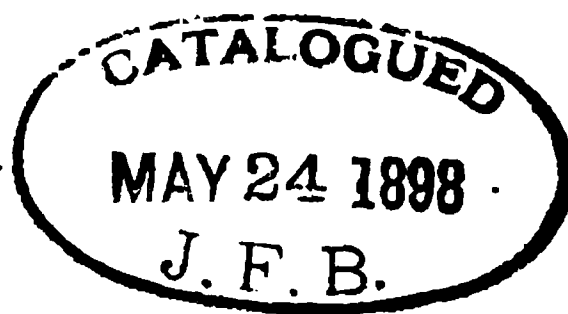
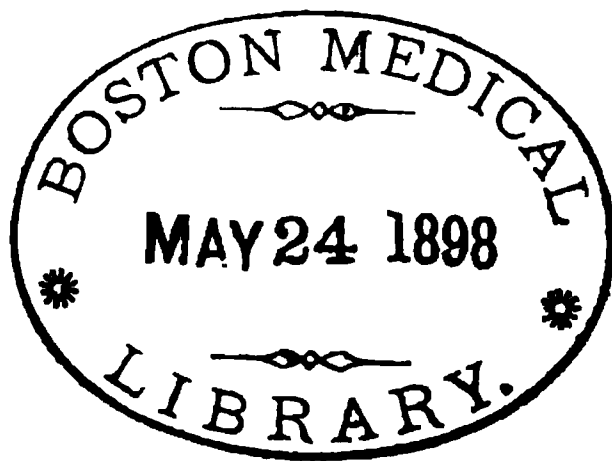
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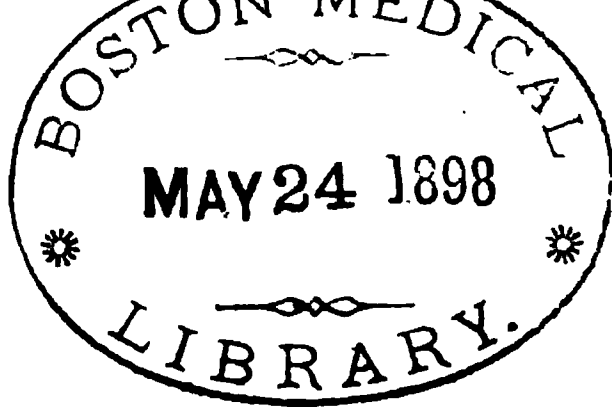
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Journal of Anatomy and Physiology.

ON THE HOMOPLASTY OF THE BRAIN OF RODENTS, INSECTIVORES, AND CARNIVORES. By GUSTAV MANN, M.D., *Assistant to the Professor of Physiology, University, Edinburgh.* (PLATE I.)

[Towards the expenses of this research a grant was made by the British Medical Association, on the recommendation of the Scientific Grants Committee of the Association. The Goodsir Prize was awarded to the Author by the Senatus of the University of Edinburgh in August 1895.]

It is the aim of this essay to investigate the relative positions of physiologically identical areas in the brains of animals belonging to different orders, *i.e.*, to study the homoplasty of the Cerebrum, and hereby to throw some additional light, *firstly*, on the homology of convolutions; and *secondly*, to ascertain the extent or degree to which the various functions have been developed in any given brain.

As representatives of the rodents, the insectivorous and carnivorous animals, I chose the Rabbit, the Hedgehog (*Erinaceus*), and the Cat, and thought my first endeavour should be to prepare the comparatively smooth brains of Rabbits and Hedgehogs in such a way as to show the minutest anatomical details for future guidance during my experimental work.

METHODS.—With this view I had recourse to my method of preparing brains, described last year in this *Journal*.¹ My method is shortly this: Anæsthetise an animal,—open the thorax and cut off the apex of the heart,—insert a glass cannula, attached to a piece of india-rubber tubing seven feet long, and tie the cannula into the ascending aorta—the other end of the tubing being attached to a funnel—raise the funnel 4–5 feet to get a sufficient pressure; wash out the brain with salt solution, and then fix it by injecting a saturated solution of corrosive sublimate in a $\frac{3}{4}$ p.c. salt solution. After the sublimate solution has been flowing for five minutes, the brain is

¹ *Journ. Anat. and Phys.*, vol. xxix., p. 1, 1894. Also in *Zeitschr. f. wiss. Mikroskop.* "Behandlung der Nervenzellen," &c., 1895.

of the consistency as if hardened for three months in Müller's fluid. There is absolutely no shrinkage, and the minutest anatomical details will be preserved. Now remove the brain, carefully dissect off the pia mater, and place, preferably for 24 hours, in a large quantity of saturated sublimate solution. Lastly, rinse the brain for half an hour in water and then photograph it, taking, of course, great care in the arranging of the light. (Plate I. shows a number of views of brains reproduced from photographs.)

As regards the EXPERIMENTAL PART of my research, the Hedgehogs and Cats were kept anæsthetised during the whole period of the experiment, while the Rabbits were anæsthetised to render the preliminary operation painless, and then allowed to regain consciousness. As far as I was able to observe, I failed to detect any sign of discomfort expressed by the Rabbit, chiefly because I dispensed altogether with the animal holder, preferring to have the animal sit in its natural position, the head being supported by the palm of my left hand, while the thumb and index-finger of the same hand were gently placed round the neck, in such a way that the tips of the fingers came to lie behind the occipital condyles.—On several occasions I have fed rabbits whose calvaria was completely removed, and they enjoyed the cabbage or bread as much as if they had not been operated on.

The experimental-room having been heated up to 75° F., and all draughts guarded against, the animals were deeply anæsthetised with ether, and then both hemispheres fully exposed from the olfactory bulb to the most posterior part of the occipital region, thus allowing one to study the whole upper surface of the brain,—carefully to measure its proportions, and further to obtain a number of precise and otherwise unattainable movements by the simultaneous stimulation of corresponding parts of both hemispheres.—Those parts of the brain which were not being stimulated I kept covered with absorbent cotton-wool.

The electrodes I employed were not the usual ball-pointed platinum electrodes, but linear ones, made by bending the ends of two pieces of copper wire so as to form loops and placing these loops in a vertical plane: looked at when on end, the negative and positive poles will appear as two parallel lines (||). The advantages of these electrodes are: (1) a given area is

stimulated more uniformly and with greater precision, and (2) there is less danger of injuring the brain.

Thus I employed as a rule electrodes the looped ends of which were 2 mm. long, and separated from one another for a distance of 2 mm., giving a surface area of 4 square mm. between the points. In the Rabbit's brain the distance between the points of the electrodes equalled only 1 mm., thus restricting the area of stimulation to 2 square mm. of the cerebral cortex.

For the simultaneous stimulation of corresponding points of both hemispheres, I employed, whenever these points were not situated in the marginal convolutions, a double electrode, which I made from two pieces of copper wire and a piece of wood, the points of the electrodes being looped as in the single electrode.

The faradic current was obtained from a Du Bois Reymond induction machine, driven by a large Daniel cell. The secondary coil was placed at first at a distance of 18 cm., and then gradually pushed up till a definite reaction was obtained. On an average a distance of 14–12 cm., and for more deeply anaesthetised animals 10–8 cm., was found to be ample. The relative excitability of various centres I have indicated, but not the absolute one.

In not a single animal have I observed epileptiform fits, although several experiments lasted six to seven hours after the preliminary operation had been performed.

THE SURFACE ANATOMY OF THE CARNIVOROUS BRAIN.

Many writers have contributed to our knowledge of the arrangement of the convolutions in the brain of Carnivora, and by the study of many genera it has been determined that in small carnivores, such as *Mustela*, three convolutions run in an antero-posterior direction, while in the Dog, Cat, and Bear four convolutions are seen. These I shall call, after Sir William Turner,¹ as follows,—(compare figs. 1, 2, 5, 8 on Plate I.),—

1. The *marginal C=a*: running along the mesial longi-

¹ Sir William Turner, "The Convolutions of the Brain: a study in Comparative Anatomy," *Journal of Anatomy and Physiology*, vol. 25, pp. 127–129.

- tudinal fissure (1), and bounded externally by the lateral (3) and coronal (8) fissures.
2. The *lateral* $C=b$: bounded externally by the medio-lateral (4) fissure.
 3. The *supra-sylvian* $C=c$: bounded externally by the supra-sylvian (5) fissure.
 4. The *sylvian* $C=d$: bounded externally by the sylvian (5), præ- and post-rhinal fissures (9).

These convolutions, according to Langley,¹ meet behind the præ-sylvian (7), or, as he terms it, "supra-orbital," fissure, to form the *anterior composite gyrus*, while to that part of the brain lying anterior to the præ-sylvian fissure, and between it and the olfactory bulb and most anterior part of the præ-rhinal fissure, this author has given the name of *orbital lobe* (orb). I myself am inclined to look on this part of the brain as forming the anterior portion of the Sylvian Convolution.

The chief fissures are the *crucial fissure* (Leuret) (2), which springs from the longitudinal one and separates the sigmoid portion of the marginal convolution (sigmoid gyrus of Flower) into a præ-crucial (præ-frontal) ($=pr$) and a post-crucial (post-frontal) ($=ps$) portion.—The *præ-sylvian* ($=7$) fissure arises from the rhinal in front of the sylvian one; it arches upwards and forwards, with its concavity placed posteriorly. The *coronal* ($=8$) fissure separates the sigmoid portion of the marginal convolution from the coronal part of the lateral convolution. The *sylvian* fissure runs backwards and upwards, and serves to divide the *rhinal fissure* into an anterior and a posterior portion. In the orbital lobe one may always distinguish a more or less deep depression, namely, the *intra-orbital fissure* of Langley. There is still another slight but constant depression to be seen about 1 cm. behind the præ-sylvian fissure; and demarcating the anterior end of the supra-sylvian C., we may call it the vertical fissure. This same fissure forms the posterior boundary of the beak-like, somewhat broadened, anterior extremity of the lateral convolution $=x$.

In the Dog, figs. 1 and 5, the sigmoid gyrus is situated at about

¹ Langley, J. N., "The Structure of the Dog's Brain," *Journal of Physiology*, vol. iv., 1881, p. 252, fig. i. In this admirable paper is contained an exhaustive account of the early literature.

the junction of the anterior and middle third of the brain,¹ and here the marginal convolution attains its maximal development, *i.e.* anteriorly, while both the lateral and supra-sylvian convolutions have undergone a special development posteriorly. But although, in the Dog, the maximum width is found in the occipital region of the lateral gyrus, one may always see at its anterior end a bulbous portion, above referred to, and lying in front of the vertical fissure, = \times .

In the Cat, four distinct convolutions are not so readily distinguished, because of an annectent convolution, which joins the supra-sylvian and the sylvian convolutions. As a rule, no indication is given as to how much of the annectent convolution belongs to the lateral and how much to the supra-sylvian convolution, but occasionally a distinct though shallow depression was seen to cross the annectent C, fig. 8, No. 5, Plate I.

The sigmoid gyrus is placed in the anterior fourth [see Sir William Turner, *l.c.*], and through its special development the marginal convolution has again obtained its maximum growth in the frontal region.

On comparing the Dog's brain with that of the Cat one is struck at once by the remarkable difference in the development of the lateral gyrus. In the Dog it is specially developed posteriorly, while in the Cat the anterior portion is by far the more bulky. The reason for this difference I shall attempt to give later.

EXPERIMENTAL EVIDENCE.

I have arranged in a tabular form the results which have been obtained by various experimentalists, amongst whom I have to mention especially: Fritsch and Hitzig, Ferrier, Paneth, Munk, Baginsky, Arloing, Krause, Semon and Horsley, Bechterew and Ostankow. I shall enumerate, from before backwards, for each convolution, the centres which have been so far discovered.

¹ Sir William Turner, "Comparison of the Convolutions of the Seals and Walrus with those of the Carnivora, and of Apes and Man." *Challenger Reports*, Part lxviii. *Journal of Anatomy and Physiology*, vol. 22, pp. 554-581; special reference, p. 562.

PHYSIOLOGY OF THE CONVOLUTIONS OF THE DOG.

(Ferrier's numbers are marked with the letter F.)

A. *Marginal Convolution.*

1. Dilatation of pupils ;—movement of eyeballs ;—head turned laterally. (F. 12.)
2. Elevation of shoulder ;—extension forwards of opposite fore-limb. (F. 5.)
3. Flexion of paw. (F. +.)
4. Retraction and adduction of opposite fore-limb. (F. 4.)
5. Hind-leg (opposite) advanced. (F. 1.)
6. Lateral or wagging movements of the tail. (F. 3.)

B. *Lateral Convolution.*

1. Closure of opposite eye ;—divergent movements of eyeballs ;—contraction of pupils. (F. 7.)
2. Eyeballs move to opposite side. There is some degree of diagonal deviation ;—pupils occasionally contract ;—eyelids tend to close, sometimes they open on application of stimulus. (F. 13.) (Arloing.)

C. *Supra-Sylvian Convolution.*

1. Bilateral adduction of vocal cords (Krause,¹ Semon and Horsley²).
2. Swallowing movements (Bechterew and Ostankow³).
3. Retraction and elevation of opposite angle of mouth. (F. 8.)
4. Retraction of angle of mouth. (F. 11.)
5. Pricking and sudden retraction of opposite ear. (F. 14.)

D. *Sylvian Convolution.*

1. See sub. No. 1 in Supra-Sylvian Convolution.
2. Opening of mouth ;—movements of tongue ;—barking and growling. (F. 9.)
3. Elevation of lip ;—dilatation of nostril. (F. 16.)

Baginsky⁴ obtained most marked ear movements from the temporal portions of the Supra-Sylvian and Sylvian Convolution.

PHYSIOLOGY OF CONVOLUTIONS OF THE CAT.

A. *Marginal Convolution.*

1. Elevation of shoulder ;—flexion of fore-arm and paw. (F. 5.)
2. Retraction and adduction of opposite fore-leg. (F. 3.)

¹ Krause, *Arch. f. Anat. u. Physiol* ; Physiol. Abtheil. 1884, p. 203.

² Semon and Horsley, *Philosoph. Trans.*, vol. 181, 1890, p. 198.

³ Bechterew and Ostankow : Schlucken u. Athmen—*Neurol. Centralbl.* 1894, No. 16, pp. 580–584.

⁴ B. Baginsky : Hörsphäre u. Ohrbewegungen : *Arch. f. Anat. & Physiol.* (Physiolog. Abth. 1891, pp. 227–235).

3. Advance of opposite hind-leg. (F. 1.)
- + No tail centre behind ansate fissure was discovered.

B. *Lateral Convolution.*

1. Elevation of angle of mouth ;—closure of eye ;—movements of eyeball. (F. 7.)
2. Eyeballs to opposite side ;—pupils occasionally contract. (F. 13.)
3. Clutching or grasping movements of paw and protrusion of nails. (F. a.)

C. *Supra-Sylvian Convolution.*

1. Adduction of vocal cords (Krause, Semon and Horsley).
2. Opening of mouth ;—movements of tongue. (F. 9.)
3. Retraction and slight elevation of angle of mouth ;—ear drawn downwards and forwards. (F. 8.)
4. Pricking of ear ;—head and eyes turn to opposite side. (F. x.)

D. *Sylvian Convolution.*

1. Abduction of vocal cords (Semon and Horsley). This centre is situated in the orbital lobe.
2. Opening of mouth (See sub "C") ;—movements of tongue. (F. 9.)

NEW OBSERVATIONS ON CATS.

Using currents of just sufficient strength to produce an effect, —employing my linear electrodes, with the points 2 mm. apart, I have been able to resolve the limb movements with greater accuracy, and have discovered the centres for extension and flexion of spinal column, for the intercostal and abdominal muscles, and lastly for the tail. All these centres are situated in the marginal convolution.

I shall record now the five most successful experiments.—(See figures Nos. 1–5, page 13.)

Experiment 1.—Medium-sized male cat. Ether and Acetate of Morphia anæsthesia.

I. *Marginal Convolution* :—Figure, Exp. 1, page 13.

1. Dilatation of both pupils, restricted to a very limited spot on the prorean convolution. To eliminate fallacy, electrodes applied to præ-crucial gyrus, the dura, and the orbital bone, with negative result, then again to point "1" with positive result.
2. Retraction of neck. Muscles on opposite side contract somewhat more vigorously

3. Retraction of upper arm.
4. Full extension of fore-limb in a vertical position. The movement may perhaps be best described as a stilting movement.
5. Extension and adduction of upper arm. Flexion of fore-arm due to biceps muscle.
6. Forward movement of fore-limb.
7. Dorsiflexion of wrist. Elevation of paw.
8. Elevation of paw more marked.
9. Fore-limb elevated to mouth. The cat was supported with my left hand, and the right leg was hanging down quite freely, but was regularly elevated on stimulating this spot.
10. Raising of fore-paw from wrist followed by flexion at elbow.
11. Adduction of upper arm.
12. Rotation outwards of fore-arm.
13. Fore-limb is adducted (the paw being in a vertical plane), due to contraction of the pectoral muscles.
14. Retraction of fore-arm, accompanied by slight outward rotation.
15. Hind-leg kicks vigorously backwards. This reaction is very readily obtained if one place the electrodes in the centre of the somewhat triangular post-crucial gyrus. In stimulating this centre it is best to lay the animal on its side, to prevent it getting a purchase on the table and suddenly elevating its head, which is apt to result in an injury to the brain.
16. Extreme flexion and abduction of hind-limb. This movement reminds one of the act of micturition in a dog.
17. Forward movement of hind-leg.

II. *Lateral Convolution.*

18. Whiskers moved forwards. Upper lip moves forwards and inwards.
19. Lower eyelid moves upwards.
20. Eye (opposite) moves inwards and slightly downwards.
21. Eye moves purely downwards.
22. Eye moves upwards and outwards.
23. Eye moves downwards and outwards.

Strength of current for Nos. 1-14 = 13-14 cm. distance of secondary coil from primary. For the hind-leg, distance was $9\frac{1}{2}$ cm. For the stimulation of the lateral convolution = 12-13 cm. were required.

Experiment 2.—Full-sized female cat. Ether and Morphia anæsthesia. Died suddenly, due to failure of heart. On post-mortem examination, we found extensive fatty degeneration. (Figure, Exp. 2, page 13.)

I. *Marginal Convolution.*

1. Retraction of fore-paw.
2. Flexion of tarsal and metatarsal phalangeal joints.
3. Flexion of knee.

4. Elevation and supination outwards of foot.
5. Retraction of hind-leg.
6. Hind-leg kicks out, and while in the backward extended position the small toe is abducted.

II. *Lateral Convolution.*

7. Opening of mouth.
8. Elevation of angle of mouth and slight shutting of eye.
9. Lower eyelid moves upwards.
10. Upper eyelid moves downwards.
- 9-10. Closure of eye.
11. Eyeball opposite moves outwards.
12. Eyeball (opposite) moves downwards.
11. and 12 = conjugate movement of the eyes, but effect on opposite eye more marked.

Experiment 3.—Full-sized male cat. Ether and Morphia anæsthesia. (Figure, Exp. 3, page 13.)

I. *Marginal Convolution.*

1. Retraction of fore-limb after it had been fully extended by an assistant.
2. Retraction of paw and stilting of fore-leg. This centre was in the præ-crucial gyrus, situated just above the middle of the crucial sulcus.
3. Retraction and pronation of fore-arm and dorsiflexion of wrist.
4. Do. but the pronation more marked. Nos. 3 and 4 close to crucial fissure in the outer part of præ-crucial gyrus.
5. Extension of fore-limb.—Forward movement in the anterior inner aspect of præ-crucial gyrus, just at origin of the prorean convolution.
6. Forearm abducted and rotated outwards; there was also a slight forward motion.
7. Elevation of paw. Rotation outwards. Abduction of paw.

In the anterior external part of præ-crucial gyrus, and close to the lateral gyrus.

8. Biceps muscle alone was felt to contract.
9. Elevation of paw.
10. Raising and retraction of shoulder.
11. Hind-leg (opposite) flexed.
12. Hind-leg (opposite) retracted.
13. Rotation inwards of foot + slight retraction.
14. Flexion of leg on thigh.
Flexion and inward rotation of foot, but not so well marked as in No. 13.
15. Head moved downwards. This was observed 8 times in succession, but the movement was very slight. The centre seems to lie in the external portion of No. 15, close to the

annectend gyrus, which joins the marginal and the lateral convolutions.

15. Dorsal muscles above shoulder-blade contract,—inner half of No. 15.

16. Contraction of extensors of dorsal vertebræ.

17. Contraction of extensors of lumbar vertebræ.

Hind-legs extended.

This movement exactly resembles that performed by a cat which, after a good sleep, is stretching itself by resting on its front-legs, arching the back downwards and fully extending its hind-legs.—On steadying the thorax and applying a somewhat weaker stream, the muscles of the opposite side were chiefly thrown into action, and this resulted in a lateral curvature of the spine, the lumbar region of the cat being lifted completely off the table.

18. Tail was drawn down as if to be put between the legs. After the stimulation had ceased, the tail was fully extended on a level with the back of the animal, and then the stimulus applied. This centre was stimulated 20 times within $\frac{3}{4}$ of an hour, and each time with positive results.

II. *Lateral Convolution.*

19. Opposite eye moves markedly outwards. Eye of same side slightly inwards.

20. Eye on opposite side moves upwards.

The results detailed above were obtained for Nos. 1–14, with secondary coil 12 $\frac{1}{2}$ –14, on an average 13 cm. removed from the primary coil. For the results sub. No. 15–18 a stronger current had to be used; for the secondary coil was at a distance of 8 cm. from the primary coil.

Experiment 4.—Female cat, on post-mortem examination found to be pregnant. (Ether and morphia.) (Figure, Exp. 4, page 13.)

I. *Marginal Convolution.*

1. Complete arrest of respiration, due to contraction of abdominal and intercostal muscles. This result was got 25 times in the course of $\frac{3}{4}$ of an hour, and there was complete arrest for 10 seconds, but beyond this length of time I did not care to prolong the stimulation, because I was afraid of killing the animal. Whenever stimulation was stopped the abdominal muscles were felt and seen to relax, the chest widened and an audible inspiration took place. To make quite sure about the contraction of the intercostal muscles, I placed the tips of the fingers of my left hand between the ribs, and then stimulated the cortical area. There was at once a vigorous contraction, and the ribs were felt to approach one another. Two assistants were also able to verify this contraction of the intercostal muscles.

2. Elevation and retraction of hind-foot.

II. *Lateral Convolution.*

3. Elevation and retraction of angle of mouth (laughing motion).
4. Closure of opposite eyelid.
5. Eye of opposite side rotates inwards.
6. Do. do. downwards.
- × Contraction of pupil (?). The contraction did not always take place.
7. Movements of the front-leg, being at one time grasping movements, and little further back walking movements, or consisting simply in the elevation of the paw.
8. Movement of hind-leg, it being as a rule drawn up.

By placing one point of the electrode on the anterior point of No. 7 and the other electrode on No. 8, peculiar walking, or rather swimming, movements were obtained.

This centre is always situated in the beaked anterior end of the lateral convolution; and because of the purposive movements of the limbs, one might consider it the centre presiding over or governing locomotion, and working conjointly with the so-called motor centres in the sigmoid gyrus, these latter being the special centres for individual muscles.

- 9 and 11. Concha of ear drawn forwards.
10. Concha turned out, ear pricked.

Experiment 5.—Large, fully-grown male cat. Ether and Morphia anæsthesia. (Figure, Exp. 5, page 13.)

- I. *Marginal Convolution.* Movements of neck, paw, leg, and tail were obtained similar to the Experiments 1–4.

II. *Lateral Convolution.*

1. Whiskers move forwards, accompanied by protrusion of lips as in kissing movement.
2. Retraction of whiskers.
3. Closure of eye on opposite side. The upper lid moves most.
4. Eyebrow pulled backwards.
5. Eye moves out and up.
6. „ „ purely out.
7. „ „ down and out.
8. „ „ up and out.
9. „ „ (same as No. 6).
10. Playing movements of opposite front-paw.
11. Walking movement. Front-leg moves most.

III. *Supra-Sylvian Convolution.*

12. Ear laid against the head, as during a fight.
13. Ear turned forwards and depressed.
14. Ear rotated inwards.
15. Before stimulation the ear was looking forwards, but on stimulation it was everted backwards.

IV. *Sylvian Convolution.*

16. Tongue pushed forwards.
17. Tongue pulled back, with the centre depressed, and the margins and the tip of the tongue raised.
18. Tongue purely drawn backwards.
19. Swallowing movements several times repeated.

RECAPITULATING shortly, we find therefore in the cat four convolutions, having chiefly the following functions :—

- I. The marginal C :—Movement of the neck, trunk, limbs, and tail.
- II. Lateral Convol. :—Movements of mouth.
Closure of eye.
Eye movements.
[Walking movements.]
- III. Supra-Sylvian C :—Ear movements.
- IV. Sylvian Convol. :—Movements of the jaws.
Movements of the tongue.
Swallowing movements.

Comparing the cerebrum of the Dog with that of the Cat, we saw that in the former the lateral convol. attains its maximum development posteriorly, while in the Cat the reverse holds good. As the area under consideration represents the visual centre, by simply looking at these two carnivorous brains one arrives at the conclusion that the visual faculties must be more highly developed in the Dog, an assumption which I believe is borne out if one watches the behaviour of these two animals. On the other hand, grasping and clawing movements are extremely well developed in our domestic cat, whose ancestors must have led an arboreal existence, and, going hand in hand with this faculty, we find a highly developed circumscribed area in the beaked anterior part of the lateral convolution, mapped out by \times in fig. 8, Plate I.

Just as the sense of vision is especially developed in the Dog, so the sense of hearing has attained a special development in the Cat; and again we find that, in connection with this sense, the feline pallium has been changed from the supposed more primitive condition, in which, *e.g.* as in *Mustela*, we have a number of

EXP. 2.

EXP. 1.

EXP. 4.

EXP. 3

EXP. 5.

EXP. 6.

EXP. 7.

EXP. 8.

concentric convolutions. I am referring now to the annectent convolution,—which joins the supra-sylvian and sylvian gyri, and the stimulation of which always leads to ear movements. In a surface view of the Cat's brain this region is seen to bulge out, and here the brain attains its maximum width. In the Dog the maximum width is attained posteriorly, due to special development of the lateral convolution. [Compare figs. 1 and 2, 5 and 8, on Plate I.]

EXP. 9.

EXP. 10.

EXP. 11.

EXP. 12.

The Anatomy and Physiology of the Insectivorous Brain.

(Compare Plate I. figs. 3 and 4.)

As far as I have been able to ascertain, the brain of our largest insectivore, namely, the Hedgehog, is always described

as perfectly smooth. This, however, is not the case. As the above photographs show, it is possible to recognise constantly two shallow depressions on the cranial surface of the pallium (7 and ?).

The greatest length of the pallium = 15 mm.

„ breadth „ = 18 mm.

The first transverse depression (No. 7) is at about the junction of the first and second fourth; if one takes the mesial longitudinal fissure as a vertical line, and then draws two lines at right angles to it, one touching the frontal, the other the occipital pole of the pallium. In the brain from which I took the above measurements, the transverse depression lay 4 mm. behind the frontal pole; it measured $4\frac{1}{2}$ mm. in length, ran downwards and slightly backwards, reaching neither the mesial longitudinal nor the rhinal fissure.

A second very shallow depression runs more antero-posteriorly, and seems to correspond to the lateral fissure (fig. 3, ?).

No trace of a convolution or sulcus could be made out on the mesial surface, but a slight depression, corresponding to the Sylvian fissure of more highly convoluted brains, I have indicated by No. 6 in the photographs 3 and 4, Plate I. I shall now shortly describe the definite centres I found in the Hedgehog's brain, and then draw conclusions as to the homology of the transverse sulcus.

After anæsthetising the animal with ether it was unrolled, the spines were clipped off close to the skin, the brain exposed in the usual way, the animal held in the left hand, and first the right side stimulated and then the left side. The same results were obtained on both sides. (See figure, Exp. 6 on page 13.)

1. Electrodes placed on both hemispheres close to the longitudinal fissure and in front of the transverse fissure
Retraction of head.
2. Behind and slightly external to No. 1 and in front of transverse sulcus = Lateral movement of head to opposite side.
3. Retraction of front-leg.
4. Elevation of front leg and paw.
5. Extension of toes of fore-limb.
6. Flexion of toes of fore-limb.
7. Elevation of hind-foot.

8. Extension of hind-limb.
9. Contraction of anus. Slight erection of penis.
10. Mouth opened widely.
11. Protrusion of tongue.
12. Retraction of tongue.
13. Grinding movements of the jaws.

We thus find that the centres for head movements lie in front of the transverse sulcus, while behind it there are placed internally the centre for the fore-limb, and externally the centre for eating movements.

On comparing the brain of the Hedgehog with that of the Dog and Monkey, it will be seen that the conclusion arrived at by Sir William Turner, namely, "that the præ-sylvian and præ-central fissures are homologous"¹—a conclusion based on Ferrier's researches—is fully borne out.

The "transverse," or as we may now term it the "præ-sylvian" fissure of the Hedgehog (=No. 7, figs. 3 and 4, Plate I) corresponds thus to the first of the three primary fissures which have been described by Pansch² as appearing on the cranial surface of the brain of the foetal dog.

In addition to the above I experimented on other two hedgehogs, with results similar to the above.

Anatomy of Rabbit's Brain.

There is a considerable literature dealing with the surface anatomy of the brain of Rodents; but in as much as this essay is only meant to establish as far as possible the homoplasty of the Rabbit's brain, I shall restrict myself to a short historical account of the pallium as described by former observers, and then pass on to a minute description of the brain as it appears when fixed by my sublimate method.

All observers are agreed in pointing out that the pallium possesses, when viewed from above, a pyramidal shape, the apex of the pyramid being placed anteriorly. Seen in profile, the brain is usually described as being perfectly flat on its vertical aspect.

As to the division of the pallium into a frontal, temporo-

¹ Sir William Turner, *l.c.* ("Convulsions of the Seals and Walrus," p. 575).

² Pansch, *Centralbl. f. d. med. Wissensch.* 1875, No. 38.

parietal, and occipital lobe, the opinion of authors varies. Bevan Lewis¹ reasons thus:—"There is no distinct frontal, occipital, or temporal lobe differentiated from the extra-limbic mass, which must be regarded as entirely constituting a parietal lobe. We therefore find no trace of a fissure of Rolando, as is seen in Osmatic Gyrencéphales (*e.g.*, Pig and Sheep). We shall, however, retain the terms frontal and occipital poles as indicative of the anterior and posterior extremity of the hemisphere, it being understood that these terms do not imply the existence of a frontal or occipital lobe."

Krause,² on the other hand, finds that "the lateral margin of each hemisphere shows a shallow posteriorly placed indentation, which corresponds to the Fossa Sylvii, and which separates the frontal from the temporal lobe. The mesial border of each hemisphere is straight, while on the posterior border the occipital lobe is seen as a slight bulging projection, covering the anterior corpora quadrigemina, and placed close to the mesial line.

Löwe³ describes the lower aspect of the Rabbit's brain thus: Laterally is seen the Sulcus collateralis (the rhinal fissure) bounding the lateral border of the Gyrus hippocampi and the mesial border of the Gyrus temporalis, which latter corresponds to the third temporal Gyrus of Man.

On the inferior aspect of the frontal lobe the Sulc. collateralis is continued as the Sulc. frontalis, and there the Gyri rectus, frontalis medius, and inferior are to be seen.

Now as to the convolutions:—

Flourens⁴ in 1858 described and figured a longitudinal sulcus running in a sagittal direction, and since then this sulcus has been seen by all anatomists who have been working at the Rabbit's pallium, but its exact extent forwards and backwards is left extremely indefinite. This sulcus evidently corresponds to the lateral fissure of the Dog's brain.

A second sulcus, running parallel to the lateral one, has been

¹ W. Bevan Lewis, "On the Comparative Structure of the Brain in Rodents," *Trans. Phil. Soc.*, vol. 173, pp. 700 and 701.

² W. Krause, *Die Anatomie d. Kaninchens in topographischer u. operativer Rücksicht*, Leipzig, 1884.

³ Löwe, *Beiträge z. Anat. & Entwickelgesch. d. Nervensystems*, vol. 1, 1880.

⁴ Flourens, *Comptes rendus*, 1858, T. 47, p. 803.

described by Eulenburg and Landois,¹ and although I have failed to see any such sulcus in the rabbits I examined, from the results of their experiments we may conclude that this second depression is the homologue of the medio-lateral fissure of the Carnivorous brain.

Ferrier² has figured in one of his drawings of the Rabbit's pallium a very distinct crucial fissure, and Réthi³ has done the same.

On the mesial aspect of each hemisphere Bevan Lewis (*l.c.*) figures a splenial fissure, consisting of a sub-frontal and a sub-parietal segment, the splenial fissure being called the limbic one. Broca also describes a splenial fissure. Andriezen⁴ mentions a shallow sulcus on the mesial aspect of the occipital portion of the brain.

THE PALLIUM OF THE RABBIT.

Comparing the photos 6 and 11 (Plate I.) with one another, it becomes at once evident that the general outline varies considerably but both brains are pyramidal in shape, with the apex looking forwards.

If one studies the surface of the pallium, the following areas may be distinguished :—

1. A marginal convolution, mapped out posteriorly by a very distinct deep depression, which may be called the posterior lateral fissure [fig. 11, 3*b*], and anteriorly by a less marked depression, namely, the anterior lateral sulcus [fig. 11, 3*a*]. Between these two depressions, exactly in the middle division of the marginal convolution, we fail to see any indication of the lateral fissure, but we notice a distinct widening of the marginal convolution, which at this point is on the way towards the formation of a sigmoid gyrus [*s*]. [See, later, experimental evidence.]
2. An occipital sulcus marking off a triangular occipital lobule [*o.l.*]. This lobule corresponds probably to the backward prolongation of the marginal convolution.
3. A præ-sylvian eminence, corresponding, as we shall see

¹ Eulenburg and Landois, *Virchow's Arch.* 68, pp. 245–271, plate 4.

² Ferrier, *The functions of the Brain*, 1886, fig. 56.

³ L. Réthi, *Sitzb. R. Acad. d. Wiss. Wien*, 1893, p. 359.

⁴ Andriezen, *Brain*, 1894,

later, to the sylvian convolution. It is marked Plate I., fig. 11, *p.s.e.*, and is seen as a distinct bulging on the lateral aspect of the brain: it commences about 8 mm. behind the frontal pole, and is about 7 mm. long in a surface view. In a lateral view of the brain (Plate I., fig. 9, *p.s.e.*), it is recognised as a well-defined eminence in front of the Sylvian fossa (6).

4. A parietal eminence, bounded anteriorly by the præ-sylvian eminence, externally by the temporal eminence; internally by the posterior limb of the lateral fissure, and posteriorly by the occipital lobule. It is marked *p.e.*
5. A temporal eminence [*t.e.*] forming the posterior inferior lobe of the pallium, and showing on its lower aspect the post-rhinal fissure, which divides it from the hippocampal convolution (figs. 9 and 10, Plate I.).
6. A Sylvian fissure (Plate I., No. 6 in fig. 9), running obliquely upwards and backwards.

RESUMÉ OF RESULTS OBTAINED BY OTHER EXPERIMENTALISTS.

To Ferrier¹ belongs the great credit of having been the first to investigate the brain of the rabbit in a thoroughly systematic manner, and no other experimentalist has, since his first publication, added so much to our knowledge. The following centres were determined:—

1. Twitching of upper lip and drawing head to opposite side.
2. Mouth drawn to opposite side, munching movements on opposite side of mouth as if eating.
3. The same results as sub. No. 2.
4. Elevation of shoulder, extension of toes. [The electrodes were placed parallel to longitudinal fissure in anterior region, where a superior external convolution is indicated.]
5. Retraction and adduction of paw and extension of toes. [In second experiment—flexion of toes.]
6. Flexion and advance of right hind-leg from extended position.
7. Munching movements of left upper lip, grinding of jaws as if eating vigorously. Head drawn to left.

¹ Ferrier, *West Riding Lunatic Reports*, 1873, vol. 3, pp. 56–60.

- 8 and 9. Forcible closure of opposite left eye.
10. Head turned to opposite side [electrodes over parietal region].
11. Munching of lips, opening and shutting of mouth.
12. Similar to No. 11. Distinct bilateral action of lips and jaws, as if eating.
13. Eye opened. Movement of ear, apparently a tendency to retraction.

Nothnagel,¹ following the advice of Prof. Heidenhain,² induced localised lesions in the brain of Rabbits in the following way: An incision was made through the scalp, and the skull pierced with a short stout needle, the handle of which acted as a guard, then a minute drop ($\frac{1}{4}$ – $\frac{1}{2}$ an ordinary drop) of a saturated watery solution of chromic acid was injected through a silver cannula. By this method two centres were discovered (see sketch of original drawing), the first of which lies 12–16 mm. posterior to frontal extremity of the brain, and which presides over the movements of the paw of the opposite side. The power of retracting the leg is completely lost after destroying this centre. The second centre lies on the lateral aspect of the brain in front of the Sylvian fossa, and was found to induce, when injured, manège-movements, *i.e.*, the animal when walking went in a circle, the direction of the movement being towards the uninjured side. Obersteiner experimented also with the Rabbit.³ Albertoni and Michieli⁴ described in 1875 three centres in the brain of Rabbits, lying behind one another, namely, centres for the lower jaw, the fore-leg, and the neck.

Fürstner and Samt made in the same year experiments on 30 rabbits, with a view of determining the accuracy of Ferrier's observations. Samt died, and Fürstner published their results in 1875.⁵

¹ Nothnagel, H., "Experimentelle Untersuchungen ü. d. Funktionen. d. Gehirns," *Virchow's Arch.*, vol. 62.

² Heidenhain, *Centralbl.* 1872, No. 45.

³ Obersteiner, "Die motorischen Leistungen d. Grosshirnrinde," *Stricker's med. Jahrbücher*, 1878.

⁴ Albertoni, P., e Michieli, M., "Sui centri cerebrali di movimenti," pp. 136–177, *Lo Sperimentale*, 37.

⁵ Fürstner, C., "Experimenteller Beitrag z. electrischen Reizung d. Hirnrinde," *Arch. f. Psychiatr.*, vi. pp. 719–732.

They found that using a current just sufficiently strong to produce an effect, that in the 30 experiments lip movements were obtained first in eighteen cases—chewing movements in eight cases, and that only in four rabbits the centre presiding over the front paw was found the most easily excitable.

To find the centres for the front paw and for twitching of the upper lip, the following directions are given :—Prolong the mesial longitudinal fissure forwards and backwards, then draw at right angles to it two lines, one passing through the most anterior part of the frontal lobe, and the other through the occipital pole. Bisect the mesial line lying between the two parallel lines, and the mid-point of the mesial line will correspond to the centre of the front-paw. If the electrodes be shifted ever so little, retraction and adduction of the leg is induced.

The facialis centre (twitching of upper lip) is stated to lie 2–3 mm. in front of a line passing through the centre for the paw movement, and at right angle to the longitudinal fissure, and on a line drawn parallel to the longitudinal fissure through the mid-point of the hemisphere.

Ferrier's points (see above, p. 19), Nos. 1, 3, 4, 7, 10, 13 yielded nothing, and the whole of the brain behind point 9 was found to be unexcitable. Ferrier's area 5 = their centre for the front paw and its stimulation produces elevation of shoulder and extension of fingers.

Ferrier's No. 6 = flexion of foot.

Between Nos. 4 and 6 = simultaneous movements of front and hind paw.

No. 2 = Fürstner's facialis centre, and below and anterior to it is the centre for biting movements, and for single closing and opening movements of the mouth. Lying posterior to this latter centre is the area which produces grinding, *i.e.*, molar movements of the jaw. Using very weak currents, partial stimulation of facial muscles led to movement of the whiskers.

Rotation of the head to one side and epileptiform seizures in 12 per cent. of cases were obtained by stimulating a centre upwards and forwards of "K," but what this letter may mean is not explained in the above paper. There is complete agreement between Ferrier and Fürstner as to the centre producing forcible closure of the eye (Ferrier's area 8). Posterior and

inferior to this eyelid centre, very marked retraction of the ear was induced.

Eye movements could not be induced; and although the eyelids were kept open, observations failed to detect any change in position.

Finally they sum up thus:

(1) Movements obtained regularly with weak currents:—

- twitching of upper lip facialis.
- eating movements.
- elevation of shoulder.
- extension of toes.
- retraction and adduction of paw.

(2) Movements not so regularly:—

- whisker movements.
- flexion of foot.

(3) Movements got with stronger streams were:—

- rotation of head.
- closure of eye.
- ear movements.

The negative results obtained in many cases are explained by the assumption that the conducting fibres are too deeply placed. This view of course does not account for the unexcitability of the grey matter.

Brown-Séguard ¹ (1875) believed to have discovered in the Rabbit a centre presiding over the sympathetic nerve, because on cauterising the middle lobe of the right hemisphere a paralysis of the cervical sympathetic nerve seemed to be induced. There was a rise in the temperature of the opposite ear, etc. This view was, however, completely disproved by the researches of Eulenburg and Landois.² These authors, as previously mentioned, describe two longitudinal sulci running parallel to the longitudinal fissure, and state that the destruction of the grey matter between these sulci leads to manège-movements of the animal towards the side not operated on. Immediately, or at the latest one to two hours, after cauterising the brain the above effect was produced, and was frequently maintained for several days in unaltered strength.

The same result was obtainable by applying common salt to the cerebrum; and the explanation offered, that the peculiar movements of

¹ Brown-Séguard, "Recherches sur l'excitabilité des lobes cérébraux," *Arch. de Physiol.* 1875, pp. 855-866.

² Eulenburg, Alb., und Landois, L., "Die thermischen Wirkungen localisirter Reizung u. Zerstörung d. Grosshirnoberfläche," *Virchow's Arch.* 68, pp. 245-271.

the animal were due to unilateral destruction of the muscle innervation.

Balogh¹ describes in the Rabbit in each hemisphere four points which induce quickened action of the heart and one place which inhibits the heart. As further ablation of the hemispheres induced quickening of the heart's beat, he supposed that the inhibitory centrum must be more developed in the brain, *e.g.*, he stimulates motor centres, induces contraction of muscles, accelerates the return of the blood to the heart, excites, &c. Therefore his conclusions are useless.

The papers by Lussana and Lemoigne,² and by Luciani and Tamburini,³ I was unable to obtain.

Tarchanow⁴ found round the "Sulcus cruciatus" motor centres for the facial muscles and the extremities, and also for eating movements.

He points out that the brain of the guinea-pig shows at birth four distinct furrows, and that the cerebrum completely covers the cerebellum; the nerves are, further, medullated. In the Rabbit, on the other hand, the fibres at birth are non-medullated.

Bufalini⁵ found that stimulation of those centres of the cerebrum which govern the movements of the jaw also lead to increased gastric secretion and to an elevation of the temperature of the stomach.

Moeli⁶ cauterised the brains of 28 Rabbits, and arrived at the following conclusion: Destruction of an area lying between the centres for lip and leg movements produced loss of muscle-sense in the opposite fore-leg. His fig. 2 shows an area for the paw centre [?].

On cauterising the area lying external to the posterior division of the lateral fissure on the right side, there resulted blindness on the opposite side. This loss of vision was very marked on the first three days, but towards the 6th day vision had improved sufficiently to prevent the animal knocking against any obstacle. Now a still greater part of the left hemisphere was cauterised, which resulted in complete blindness of the right eye. No improvement whatever by

¹ Balogh, K., "Untersuchungen ü. d. Funktion d. Grosshirnhemisphären u. d. kleinen Hirns," *Sitzbr. d. k. ungar. Akad. d. Wiss.*, 7, vol. 8. (1876). [Hungarian.]

² Lussana, Ph., et Lemoigne, A., "Des centres moteurs encéphaliques, Recherches physio-pathologiques," *Arch. de. physiol. norm. et pathol.*, 1877, pp. 119-145, pp. 342-399, plate 4. *Sperimentale* 39, pp. 372-414 and 480-520.

³ Luciani and Tamburini, "Sulle funzioni del cervello. 1. a. comun. Sui centri psico-motori corticali," 8. 7 Stn. Reggio-Emilia, 1878.

⁴ Tarchanow, J. R., "Über psychomotorische Centren bei neugeborenen Thieren u. ihre Entwicklung unter dem Einflusse verschiedener Bedingungen," *Militärarzt Journal*, Oct. and Nov. 1878. [Russian.]

⁵ Bufalini, G., "Dell' influenza dell' eccitazione della corteccia cerebrale sulla secrezione gastrica. Rendiconto della ricerche sperimentali eseguite nel gabinetto fisiol. di Siena," Anno. 1878-79. II. 55-59. Siena, 1879.

⁶ Moeli, C., "Versuche an d. Grosshirnrinde d. Kaninchens," *Virchow's Arch.* 76, pp. 475-484, plate 7, figs. 1-3.

the 6th day, when the animal had to be killed because of convulsions. The left eye was able to see, and no such symptoms as resulted from the cauterisation of the right hemisphere could be detected.

The vision-centre determined in this way by Moeli corresponds to Ferrier's centre "8," which, as we saw above, leads to closure of the eye, and corresponds to centres which give rise to definite eye-movements (see later).

Réthy¹ has made the centres for chewing and swallowing his special study. He describes and figures a centre lying anterior and external to the motor area for the front-leg, and states that from its anterior and external portion ruminating, i.e. horizontal, movements may be obtained, while biting or gnawing movements are governed over by those parts of the centre lying nearest the leg area.

Réthy states definitely that his centre is a co-ordinating centre, and that it does not preside over single muscles. Its stimulation produces all the movements of ordinary chewing, which are frequently followed by an act of deglutition. That the swallowing was not induced reflexly by sensory impulses passing from the mouth to the brain was determined thus:—the lips, tongue, palate, and jaw were removed and the brain again stimulated:—deglutition occurred as before.

Spencer² has investigated, amongst other animals, also the Rabbit, to determine the influence of a faradic stimulation of the brain on the act of respiration. Two photographs of the Rabbit's brain are given and the following centres are described:—"When viewing the dorsal aspect of the rabbit's brain . . . an artery is seen coming up between the edge of the hemisphere and the falx cerebri, and then turning over on the convex surface and running outwards in a line which suggests the position of the crucial sulcus in the Cat and Dog. When the pia mater is carefully stripped off, a groove remains. This vessel serves to indicate the place where marked acceleration can be obtained in this animal when the electrodes are placed astride of the vessel near the margin. An area of 2 mm. in diameter overlapping the margin, i.e. extending a little way on to the mesial surface, is about the limit within which this phenomenon is markedly represented."

I have given Spencer's words verbatim, because I failed to produce accelerated breathing in non-anæsthetised animals. The area in question is situated, as measurements of the photograph have shown me, exactly at the junction of the first and second fourth.

Slowing and arrest of respiration were brought about by stimulating an area just outside the olfactory tract in front of the point where the tract joins the temporo-sphenoidal lobe. We know that stimulation of the olfactory nerve, e.g.

¹ Réthy, L., "Das Rindenfeld, die subcorticalen Bahnen u. d. Coordinations-centrum d. Kanens u. Schluckens, *Sitzber. K. Akad. d. Wiss. Wien*, 1893, p. 359.

² Spencer, W. G., "The effect produced upon respiration by faradic excitation of the Cerebrum in the Monkey, Dog, Cat, and Rabbit," *Philosophical Transact.* vol. 185, 1894, p. 609.

through ammonia, will also produce arrest of respiration (G. M.).

Over-inspiratory Clonus was obtained by stimulating the junction of the olfactory bulb and tract, and on continuing to apply the stimulus backwards along the olfactory tract, was traced into the uncinate convolution of the temporo-sphenoidal lobe.

NEW OBSERVATIONS ON THE BRAIN OF RABBITS.

I. *Method of locating the various centres.*

The way I proceeded to determine with absolute preciseness the position of each centre was as follows:—

After fully exposing the brain, the periosteum was stripped of the posterior part of the nasal bones, and they were marked with a deep line running across and at a right angle to the mesial plane. Where this mark crossed the junction of the two nasals, a spot was obtained from which, as a fixed point, all distances in an antero-posterior plane could be readily measured.

When experimenting, *e.g.* on the marginal convolution, I ascertained first of all how far forwards it was possible to obtain a definite reaction. Whenever this point had been found, its distance from the mark on the nasal bone was determined by placing one limb of the pair of compasses on the nasal bone and the end of the other limb midway between the two points of the electrodes. Then the distance was expressed in millimetres, say, for example, 20 mm. = tilting movement of opposite fore-limb. In this way every millimetre of the whole of the marginal convolution was investigated, but whenever an area outside this convolution had to be marked down for future comparison, a double measurement was required, and I proceeded by drawing through the area in question an imaginary line, intersecting the longitudinal fissure at a right angle. Then the distances from the point of intersection to the mark on the nasal bones and to the centre of the area under observation were noted down.

When working at the lateral and inferior aspects of the cerebrum I made use of photographs showing a brain with a printed scale, each mesh of which equalled 2 mm., and it was found best to take measurements in these cases from the most anterior part of the frontal lobe, using the rhinal fissure as an

abscissa. [See figure, Exp. 11A, page 14, lateral view of a Rabbit's brain, with a mm. square scale superimposed.]

As soon as the experiment was finished the animal was killed with chloroform, and then the following measurements taken :

1. Distance of mark on nasal bone from the most anterior part of the frontal lobe.
2. The total length of the pallium.
3. The total width of the pallium at the indentation corresponding to the Sylvian Fissure and at the broadest point of the pallium, *i.e.* in the temporo-parietal region.

The figures giving the distance of each area from the landmark on the nasal bone were converted into figures expressing the distance of each centre from the frontal pole ; an enlarged outline of each brain was then drawn to scale on paper ruled into squares, and each centre put into its place. [See maps illustrating the experiments, pages 13, 14.]

No reaction has been recorded which was not obtained at least twelve times in each respective centre, an interval of a half to one minute elapsing between each new application of the electrodes.

Experiment 7, Fig. on page 13.—Female rabbit, rather small. Total length of brain 32 mm. Length from frontal pole to pineal body 29 mm. Width in parietal region of one hemisphere $13\frac{1}{2}$ mm.

No. on Map.	Distance from Frontal Pole.	Effect on Opposite Side.	
1	4 mm.	Head moves laterally and downwards.	
2 and 3	7, 9	Head moves purely laterally.	
4	11	Head rotates out and up.	
5	12	Head moves as sub. No. 4 but more vigorously.	
6	$13\frac{1}{2}$	Head rotates especially upwards.	
7	15	Head drawn purely upwards, probably due to bi-lateral stimulation.	
8	16	Paw raised. Retraction of upper arm.	
9	17	Fore-limb straightened and abducted.	
10	19	Fore-limb fully flexed.	
11	20	Hind-foot flexed.	
12	$25\frac{1}{2}$	Both hind-legs kick out as in ordinary locomotion.	
		Distance from Mesial Line.	
13	3	3-4 mm.	Elevation of alæ of nose.
14	4	3-4	Retraction of angle of mouth.
15	6	3-4	Retraction of whiskers.
16	9	3-4	Upper lip drawn up.

It will be seen that the centres for the neck, arm, and leg lie behind one another, and close to the mesial line, while anteriorly and external to the marginal convolution are the centres for facial movements.

Experiment 8, Fig., page 13.—Full-grown male rabbit. Length of brain 35 mm. Width 10 mm. behind the frontal pole = 10 mm. Greatest width of each hemisphere in the temporo-parietal region = 15 mm. Brain shows an abnormally oval outline.

No. on Map.	Distance from Frontal Pole.	Effect on Opposite Side.	
1	6 mm.	Head moves laterally.	
2	7	Head moves laterally and downwards.	
3	9	Head moves specially laterally, with slight tendency to rotation.	
4	10	Head rotates. When both hemispheres are stimulated, head is drawn purely back.	
5	11	Head rotates.	
6	12	Head rotates and mouth lifted up.	
7	14	The upward movement is more marked.	
8	15½	Apparent retraction of head, due to shrugging of shoulders.	
9	16	Fingers spread.	
10	18½	Arm supinated inwards.	
11	18¾	While in a prone position, the wrist is dorsiflexed and fingers are spread.	
12	20½	Abduction and slight retraction of arm.	
13	21	(Just external to marginal convolution) = Elevation of shoulder.	
14	23	" " " = Abduction of arm.	
		Distance from Mesial Line.	
15	10	6¾	Retraction of the cheek.
16	12	8½	Chewing movements.

Experiment 9, Fig., page 14.—Large male rabbit, fully grown.
Length of brain 37½ mm. Width of brain 32 mm.

No. on Map.	Distance from Frontal Pole.	Effect on Opposite Side.	
1	6 mm.	Head moved down and slightly lateral.	
2	7½	Head moved purely laterally.	
3	9	Head feebly rotated.	
4	10	Rotation well marked.	
5	- 12	Head slightly retracted, but well elevated.	
6	+ 12	Head especially elevated and slightly retracted.	
7	13	Head purely retracted.	
8	14	Head purely elevated.	
9	15	Head slightly elevated, with marked lateral movement.	
10	16½	Fingers are spread.	
11	17	Paw is elevated.	
12	18	Hand clasps. Feet resting, the thorax is thrown forwards.	
ELECTRODES PLACED ON BOTH SIDES.			
13	28	Adduction of thigh.	
14	29	Flexion of foot on leg, } also slight tail movements. Flexion of leg on thigh, }	
15	30		
		Distance from Mesial Line.	
16	32	...	Tail moves upwards and then defæcation. Within ten minutes the animal was made to defæcate four times.
17	18	6½ mm.	Animal turns towards opposite side, due to lateral curvature of the spine. Mouth is brought on a level with the shoulder-blade. On stimulating the corresponding region on the opposite side, the same results, but in the opposite direction, were obtained, accompanied by a few chewing movements.
18	18	11	Animal is in sitting posture, but on stimulation moves its head forwards and somewhat laterally towards opposite side as if in search for food.
19	20	10	Movement of nostrils, and head is turned to opposite side.
20	20	15	Head is lifted up.
		Shaded area :	When stimulating this region, I have found it best to separate the points of the electrodes six to seven millimetres, and to place them antero-posteriorly.

Experiment 10, Fig., page 14.—Male rabbit, full grown.

No. on Map.	Distance from Frontal Pole.	Distance from Mesial Line.	Distance between Prim- ary and Secondary Coil.	Effect.
	5 mm.	3½ mm.	12 cm.	Alae of nose elevated. Sniffing move- ments (conduction to olfactory bulb?)
6		3½	13½	Elevation of hyoid bone, as if about to swallow.
7		3½	"	Eversion of upper lip.
9½		4	"	Retraction of whiskers.
10½		4	14½	Retraction of angle of mouth.
11½		4½	14	Elevation of angle of mouth.
10		mesial line.	13½	Head moves laterally.
ELECTRODES PLACED ON BOTH SIDES.				
12			10½	Points of electrodes 4 mm. apart. Animal sitting quietly with mouth 2 inches above table; on closing key no reaction was obtained. The elec- trodes were then gradually moved backwards without lifting them off the brain.
14		...	...	Head slightly elevated.
16		...	...	Very marked elevation of chin.
19½		...	...	Head pushed forwards, and accordingly, as electrodes were placed more to- wards one side, a movement forwards towards the opposite side was obtained.
20		1½ mm.	14	Adduction and minimum forward move- ment of opposite fore-limb.
12a	20	1½	11	Abduction and tilting movement of

Experiment 11, Figs. 11A and 11B, page 14.—Fully-grown female rabbit.

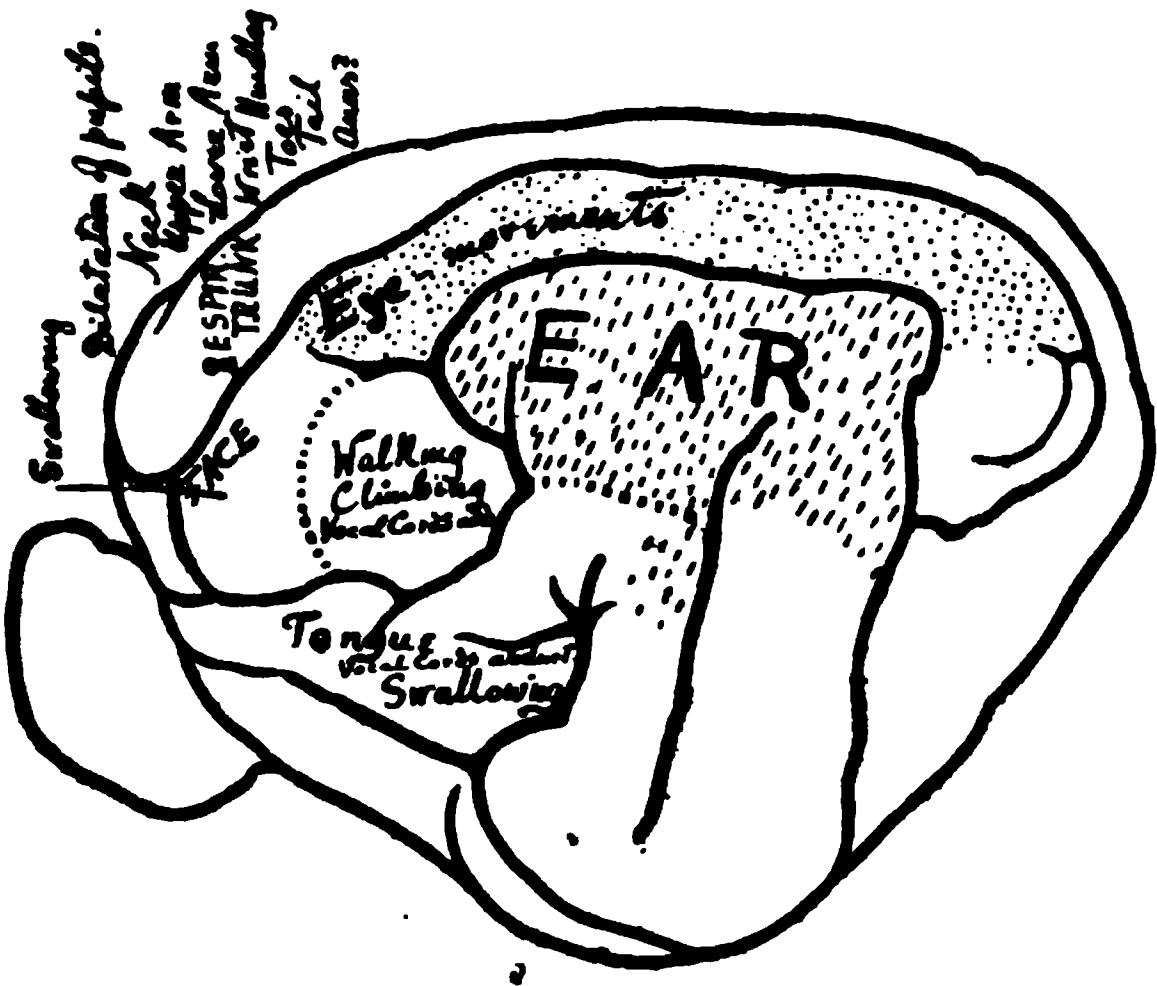
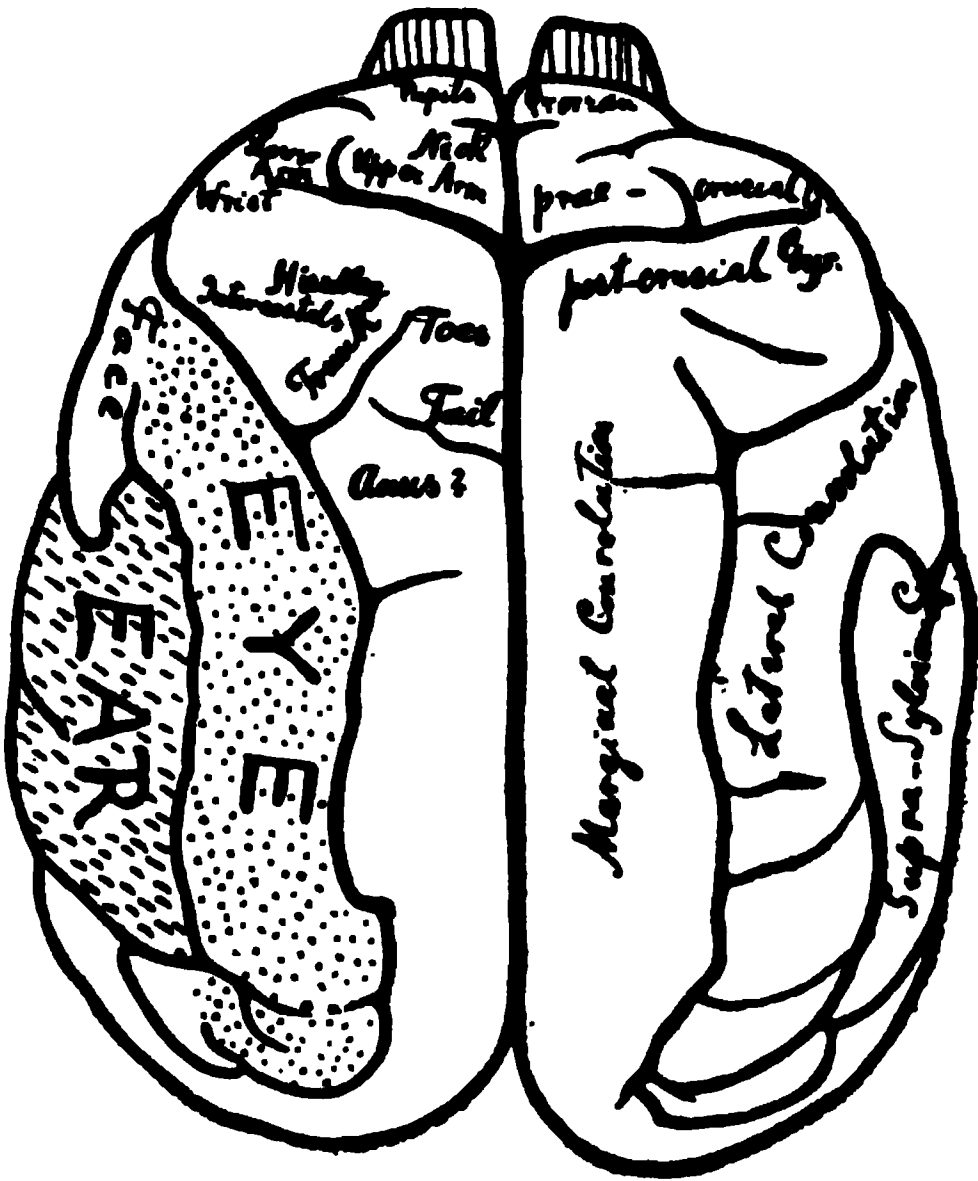
The steps in the preliminary operation, performed under deep anaesthesia, were shortly these :—

The cornea was removed,—the lens and vitreous humour extracted, taking care not to injure the ciliary processes and the retina, to prevent all bleeding. One long incision was then made from the middle of the nasal bones to the occiput;—the periosteum detached and the masseter muscle separated from its cranial insertion;—then removal of the frontal and parietal bones, the anterior and posterior supra-orbital processes, the zygomatic arch, the masseter muscle, the squamous portion of the temporal bone, and the coronoid and condyloid processes of the lower jaw. The next step consisted in compressing the bulb of the eviscerated eye, taking care not to pull on the optic nerve;—then, lastly, removing the lachrymal gland, and securing the optic nerve with its vessels by means of an artery clamp.

Whenever this preliminary operation was completed the dura was removed, the brain was carefully wrapped up in absorbent cotton-wool, and the animal not disturbed for three-quarters of an hour, because the ether narcosis had to pass off, and the animal to pass into as normal a condition as possible by sleeping for 30 to sometimes 60 minutes.

By the above operation the pallium is fully exposed on one side, the rhinal fissure is seen, and is made use of as an abscissa line for the calculation of the distances of the various centres.

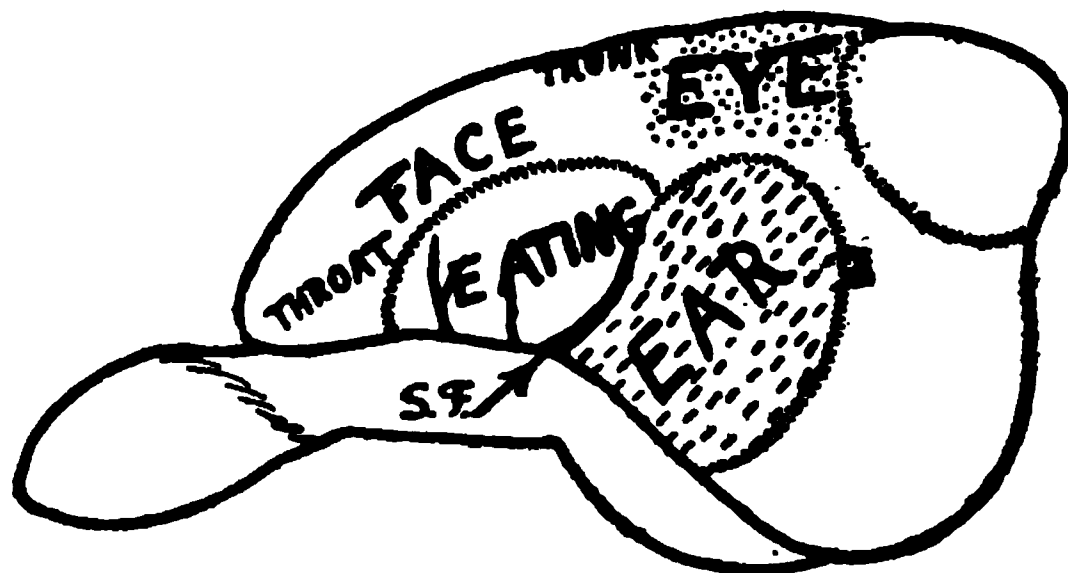
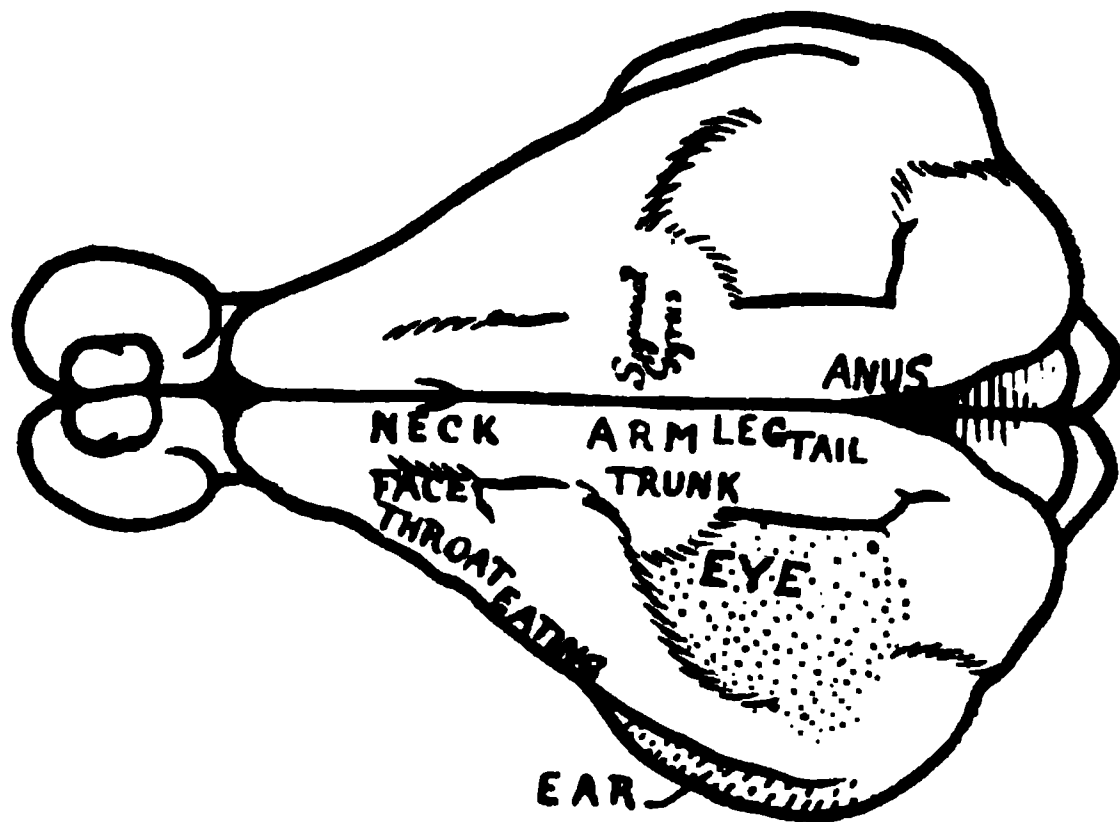
No. on Map.	Effect on Opposite Side.
1	Upper lip purely retracted.
2	Whiskers retracted.
3	Upper and lower lip both protruded.
4	Lower lip drawn down.
5	Cheeks drawn in and lips suddenly separated, giving rise to a very marked smacking sound.
6	Lips separate first. This is followed by the lower jaw being drawn down.
7	Tongue is pushed forwards without any lateral deviation.
8	Tongue retracted.
9	Palate is raised.
10	Gnawing movements, <i>i.e.</i> mouth opens and closes.
11	Lateral, <i>i.e.</i> ruminating, movements of lower jaw.
12	Eye looks <i>downwards</i> and backwards.
13	Eye looks <i>upwards</i> and forwards.
14	Eye looks <i>forwards</i> .
15	Eye looks <i>backwards</i> and downwards.
16	Eyebrow is elevated. Opening of eye due to raising of upper eyelid.
17	Concha of semi-elevated ear is turned <i>backwards</i> .
18	Concha of ear, being widely open, everted, and elevated, is turned <i>forwards</i> .
19	Concha is moved <i>forwards</i> and slightly elevated.
20 & 22	Ear is raised : this is best seen and without any additional movement at area No. 22.
21	Ear is appressed, <i>i.e.</i> concha lying perfectly flat is seen to be still more adducted.



Brain of Cat.

Recapitulating shortly the results obtained by the experimental part of the research, we find—

1. The psychomotor centres for the neck, arm, leg, tail, and anus lie, in the order indicated, from before backwards close to the mesial longitudinal fissure.



Brain of Rabbit.

The centres for the arm and trunk lie in the bulging part of the marginal convolution, giving rise to a primitive sigmoid gyrus.

2. Facial movements are produced by centres lying external to the neck centres, while eye movements are produced from centres lying external to the posterior limb of the lateral fissure.

In the carnivora the centres for facial and eye movements lie in the lateral convolution; we have therefore, as regards the second external convolution, the same arrangement in rodents and carnivores.

3. The Sylvian Fissure forms in the Rabbit a sharp line of demarcation between the centres presiding over eating movements—situated anteriorly—and the centres presiding over ear movements—situated posteriorly. Both the eating and ear centres may be recognised as definite eminences, but no trace of sylvian or supra-sylvian tiers are to be made out. It may, however, be permissible to apply the term of præ-sylvian eminence to the region lying in front of the sylvian fissure and above the præ-rhinal fissure, while that part of the pallium lying behind the sylvian fissure and just above the anterior half of the post-rhinal fissure may be called the temporal eminence.

The præ-sylvian eminence corresponds physiologically to the orbital lobe (Langley) and the præ-sylvian portion of the sylvian (and perhaps supra-sylvian) convolutions, because on stimulation eating movements result.

Above, I have stated that I succeeded in getting a centre for purposive walking movements in the Cat. No such centre could be detected by faradic stimulation in Rabbits, but it must be borne in mind that Nothnagel succeeded in producing manège-movements in Rabbits by cauterising a portion of the brain, which, as regards position, might very well be considered to be homologous with the Cat's brain.

Just as there is situated in the anterior end of the lateral convolution a special, and we may say highest, centre which apparently presides over the so-called motor centre proper, so there is an analogous higher centre which presides over the complicated mechanism employed in eating and swallowing movements: this higher centre is situated just external to the sigmoid gyrus and somewhat anterior to it, both in the Dog (Ostankow and Bechterew), the Cat (G. M.), and the Rabbit (Réthi), while the true motor centres lie close to the rhinal fissure in the orbital lobe (G. M.)

The second or lateral convolution is, to its greatest extent, the centre presiding over eye movements, there being circumscribed areas for each of the different movements of the eye. Similarly,

the third convolution presides over the various ear movements; and inasmuch as I have been unable to obtain these eye and ear movements by the stimulation of the sigmoid gyrus, which presides over the neck, trunk, and limb muscles generally, we must regard the combined motor areas in the carnivora and insectivora as very extensive indeed.

In the experiments cited above no centres for the anus and bladder in the Cat have been indicated, but repeatedly I have got defæcation and micturition by stimulating the region round the tail centre. In the Rabbit one may obtain constantly dilatation of the pupil by stimulation of the anterior part of the psycho-motor area presiding over eye movements, while by stimulation of the posterior portion one gets almost constantly contraction of the pupil.

In the Hedgehog I have still to discover the extent of the motor areas presiding over the eye and ear movements, and hope to do so shortly.

DESCRIPTION OF PLATE I.

- No. 1. Dog's brain seen from above.
- „ 5. Dog's brain seen in profile.
- „ 2. Cat's brain seen from above.
- „ 8. Cat's brain seen in profile.
- „ 3 and 4. *Erinaceus* brain in $\frac{3}{4}$ and $\frac{1}{4}$ view.
- „ 6 and 11. Rabbit's brain seen from above.
- „ 9. Rabbit's brain in profile.
- „ 7. Rabbit's brain seen from behind.
- „ 10. Rabbit's pallium, the cerebellum and mid-brain removed.

DESCRIPTION OF FIGURES AND LETTERS.

- | | |
|---|------------------------------------|
| <i>a</i> = marginal convolution
<i>b</i> = lateral convolution
<i>c</i> = supra-Sylvian convolution
<i>d</i> = Sylvian convolution
<i>e</i> = olfactory lobe
<i>or</i> = orbital lobe
<i>s</i> = sigmoid gyrus
<i>v</i> = vertical fissure
<i>clm</i> = cerebellum.
<i>m.c.</i> = marginal convolution.
<i>o.l.</i> = occipital lobe.
<i>p.e.</i> = parietal eminence.
<i>pn.b.</i> = pineal body.
<i>p.s.e.</i> = præ-Sylvian eminence.
<i>p.f.</i> = post-rhinal fissure.
<i>sph.l.</i> = sphenoidal lobe.
<i>t.e.</i> = temporal eminence. | } in the brain of the Dog and Cat. |
|---|------------------------------------|
1. Longitudinal fissure.
 2. Crucial fissure.
 - 3A. Præ-lateral, 3B. Post-lateral fissure.
 4. Medio-lateral fissure.
 5. Supra-Sylvian fissure.
 6. Sylvian fissure.
 7. Præ-Sylvian fissure.
 8. Coronal fissure.
 9. Rhinal fissure.

ON THE CLINICAL VALUE OF THE FOUR-ROOT
THEORY OF THE CRANIAL NERVES. By T. K.
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Royal Infirmary, and Pathologist to the Victoria Infirmary
of Glasgow.*

THE distinction between anterior and posterior roots of spinal nerves is at once obvious, and Sir Charles Bell showed, early in the present century, the associated difference in function between the two. Bell also noticed, long ago, that the cranial nerves are arranged in two linear series, and he thought that the lateral group (which he classed with the phrenic nerve and the posterior thoracic or external respiratory nerve) were especially connected with respiration. Dr Alex. Hill noticed, at a more recent date, that advantage might be taken of the spinal accessory nerve to obtain a more accurate classification of the cranial and spinal nerve roots. In some parts of the spinal cord, the lateral portion of the anterior horn is distinctly recognisable as a lateral horn, though, in the cervical and lumbar enlargements, this blends with the anterior horn. The lateral horn is also spoken of as the intermedio-lateral tract (Lockhart Clarke), or the intermediate process (Gowers). Its significance is only ascertainable on examination of the upper part of the spinal cord, where we find that it is absorbed by the spinal accessory nerve. The anterior motor, lateral motor, and posterior sensory constitute, therefore, three distinct kinds of nerve roots.

Clarke's column (posterior vesicular column, or Stilling's dorsal nucleus) is not continuous throughout the cerebro-spinal axis, but is so well marked where it exists as to demand careful attention from anatomists and physiologists. These cells are present in the dorsal and upper lumbar regions, and are represented also in part of the sacral region of the cord; while Ross's suggestion is pretty generally accepted that the nucleus of the vagus in the medulla is an enlargement of the upper end of the same column of Clarke. It is probable that the cells of the substantia ferruginea in the locus cœruleus belong to the

same series. This intermittent vesicular column has been described as the "visceral" column, and Dr Gaskell thinks that it gives origin to efferent visceral nerves, viz., anabolic or inhibitory nerves to the splanchnic glandular system, and to the muscles of the viscera and of the vascular system. Gaskell supposes that the solitary cells of the posterior horn also give rise to efferent nerves for viscera, viz., katabolic or motor nerves to the visceral muscles (1).

Leaving out of consideration the function of the solitary cells, Dr Hill's theory, as further developed by Dr Gaskell, assumes that four great classes of nerve fibres emerge from the cerebro-spinal axis, viz., anterior (motor), lateral (motor), visceral, and posterior (sensory). Throughout almost the whole length of the spinal cord the first three sets pass out together by the anterior roots, while the sensory element alone occupies the posterior gangliated root. In the cervical region of the cord, the lateral motor fibres separate themselves from the other constituents of the anterior roots, and constitute a lateral root (spinal accessory nerve).

In extending this theory, as Dr Hill does (2), to the nerves arising from the axis higher up, we have two guides of great value: first, the line of exit of the cranial nerves; and second, the arrangement of the nuclei of the same nerves. A mere glance at the external appearance of the medulla is enough to show that its nerve roots are arranged in two longitudinal series. One set of roots arises between the olive and the pyramid, marking off what Flechsig calls the lateral area of the medulla from the anterior area. These are the rootlets of the hypoglossal, and their line of origin is continued brainwards by the sixth nerve, and still further forwards by the third nerve. Investigation by means of sections shows that the nuclei of these different nerves are in the same (interrupted) line. So far as its nucleus is concerned, though not as regards its mode of exit, the fourth nerve also belongs to this group, for the nucleus is practically continuous with the posterior end of the third nucleus. These nerves are all, speaking generally, motor in function.

The other set of issuing cranial nerves are placed more laterally, and separate the posterior from the lateral area of the

medulla. These are, in order from behind forwards, the spinal accessory, vagus, glossopharyngeal, facial, and trigeminus. The spinal portion of the spinal accessory is motor, and arises from the lateral horn of the cord. The glossopharyngeal and vagus, which may be taken together, arise from nuclei of several kinds. The nucleus ambiguus is generally admitted (though Dr Gowers rather doubts (3) the accuracy of this view) to be the motor, or at least one motor root of these nerves. This nucleus is in the same line with the facial nucleus higher up, and with the nucleus of the motor division of the fifth nerve still higher. We find, then, on the one hand, the twelfth, sixth, and third nerves arising in one anterior series from grey matter which represents the anterior horn of the spinal cord, displaced dorsally when the medulla opens out in the fourth ventricle; and, on the other hand, the motor portion of the tenth and ninth nerves, the entire seventh, and the motor part of the fifth, arising in one lateral series from grey matter representing apparently the lateral horn of the cord.

For the purpose of this essay, it is not necessary to go further into Dr Hill's theory (as, for instance, to show the serial homology of the sensory or of the visceral roots), because my object here is to apply clinical and certain other practical tests, with the view of discovering the true value of this theory in clinical research. It will be sufficient, then, for this end, to deal only with the anterior motor and lateral motor series of roots, leaving the others out of consideration altogether.

I should like to say at the outset that Dr Hill's theory strikes me as one of great beauty, and (apart from that portion of it which deals with the connections of the visceral column,—a portion which I cannot fully accept) of great scientific worth. Indeed, there is so much truth in it that unless we keep steadily observing as well as speculating, very slight errors in it may lead us far astray. Dr Hill, be it remarked, frankly declares that "few of the cranial nerves are what might be termed 'pure' nerves" (4). Recent observations furnish much room for doubting whether, in the end, we shall be able to consider any cranial nerve "pure."

I shall now bring together facts which show that even those cranial nerves which, on a first examination, appear to consist

of fibres belonging wholly to one of Hill's four sets of root-fibres, contain, as a matter of fact, fibres belonging to one, or even more, of the remaining sets.

The facial nerve and its nucleus belong properly to the lateral series of cranial nerves and nuclei; yet there can be little doubt that this nerve contains fibres from cells in the anterior series of nuclei, and in particular the nucleus of the third and the nucleus of the twelfth nerve.

1. Facts in favour of the view that some fibres issuing from the third nucleus are present in the trunk of the facial nerve.

(1) The escape of the upper part of the face in ordinary hemiplegia, while the lower part is affected, though all parts alike are supplied by the facial nerve, suggests that the upper facial muscles are innervated in a different manner from the lower. Still, this argument is of little value by itself, because it is as easy to suppose that the upper part of the face is more completely represented in both sides of the brain than is the lower part.

(2) When a person looks upwards, and especially if he does so suddenly and strongly (third nerve), he is very likely to raise his brows also by contraction of the frontalis muscles (seventh nerve). This suggests a close connection between the origins of the third and seventh nerves. Here again, however, the connection in question may be, not between the nuclei, but in the cortex; and on the whole, perhaps, the latter view is the more likely.

(3) The probable connection between the third and seventh nuclei is shown in a much more forcible manner by the intimate relation between the upward rotators of the eyeball (supplied by third nerve) and the orbicularis palpebrarum (supplied by seventh nerve). When a person looking straight forwards lets his eyes close very gradually, the last thing he sees (and this is indistinct, because the image falls on a peripheral part of the retina) is the lower part of the visual field. When the eyelids are gently closed, the eyeballs assume the position of rest, which is probably nearly the same as the forward gaze. If the person's upper eyelid be secured by the observer, so that the eye cannot

be closed, and the person under observation be then told to shut his eye, the eyeball will rotate upwards. If he fixes his gaze on some object right ahead of him, the eyeball will not rotate upwards so readily; but if he be urged to endeavour more strongly to close the eye which is being held open, the ball will rotate strongly upwards.

This phenomenon is well seen in any case of Bell's paralysis, but must not be regarded as a paralytic symptom. It is simply the result of a strong effort on the part of the patient to shut his eye when he is told. In facial palsy of the peripheral type, an ordinary effort is insufficient to close the eye, and the patient accordingly tries hard to do as he is told; this it is that causes the upward rotation.

(4) Mendel communicated to the Medical Society of Berlin, on the 9th Nov. 1887, the results of three experiments he had made, after Gudden's method, on a rabbit and two guinea-pigs. The operation was performed on each animal when it was a week old. The upper and lower eyelids, and the orbicularis palpebrarum and frontalis muscles were extirpated. (In the rabbit this can be done without injury to muscular fibres of the levator palpebræ, which sends only a tendinous expansion into the upper lid.) The rabbit died of an epidemic disease when five and a half months old, and the guinea-pigs were killed when ten months old. The facial nucleus was absolutely alike on the two sides, and quite normal. The facial trunk was slightly thinner on the side of operation than on the other side. Marked changes were discovered in the oculomotor nucleus of the side operated on, the ganglion-cells being greatly reduced in number (5).

The significance of these results is great and obvious. Extirpation of a muscle supplied by the seventh nerve was followed by some wasting of this nerve. But the seventh nucleus was normal, whereas part of the third nucleus was wasted. Therefore the seventh nerve must get some of its fibres from the third nucleus.

Mendel suggested that the path of connection between the third nucleus and seventh nerve is the posterior longitudinal bundle. As we know that this bundle does connect the sixth nucleus with the contralateral third nucleus, for purposes of

conjugate lateral movements of the eyeballs, Mendel's theory is very likely to be correct.

This investigator could only find one published case in support of the view that the same arrangement might obtain in man which he had found to exist in other animals. This single case had been published in January 1887. It was one of ophthalmoplegia externa, with diminished faradic excitability of the muscles supplied by the upper part of the facial nerve. There was, however, no post-mortem.

In the course of the discussion which followed Mendel's paper, Uhthoff recalled several cases of ophthalmoplegia externa which appeared to support Mendel's hypothesis.

(5) Tooth and W. A. Turner (6), who first, I believe, brought Mendel's experiments into prominence in this country, deduced similar inferences from microscopic investigation of a case of bulbar paralysis. The ascending limb of the seventh nerve, which is supposed to include all the fibres from the nucleus proper, was deeply degenerated, whereas the issuing root, though unduly small, contained many normal fibres. These fibres, therefore, must have come from some other source than the seventh nucleus. They probably travelled from the third nucleus, which was healthy, by way of the posterior longitudinal bundle, to join the seventh nerve and be distributed to the unaffected muscles of the face, viz., the frontalis, corrugator supercilii, and orbicularis palpebrarum (oculo-facial group).

(6) On the 1st April 1893 a leading article in the *Lancet* proceeded thus:—"If a case of total ophthalmoplegia were observed in which the frontalis and orbicularis palpebrarum were affected, whilst the lower facial muscles escaped, the clinical evidence for the hypothesis would be fairly complete." "For the firm establishment of [this theory], there seems now only to be necessary a case of the crucial character already alluded to."

A week later, Dr Fred. J. Smith wrote (7) saying that he had met with a case of the kind, and had just transferred it to Dr Hughlings Jackson.

In July 1893 Dr Hughlings Jackson published a paper on "Two cases of Ophthalmoplegia externa with paresis of the

orbicularis palpebrarum (illustration of Mendel's hypothesis)." The second case was that sent by Dr Smith, and a third case was referred to at the close of the paper. Dr Jackson, therefore, was able to produce clinical evidence, as Tooth and Turner had already produced anatomical evidence, in support of the hypothesis which Mendel had advanced on experimental grounds only.

The conclusion seems unavoidable, that some fibres of the seventh nerve are derived from the third nucleus.

2. Facts in favour of the view that some fibres issuing from the twelfth nucleus are present in the trunk of the facial nerve.

(1) When a person causes the transverse muscular fibres of his tongue to contract, he cannot prevent the orbicularis oris contracting simultaneously. This suggests that a very intimate relationship exists between the nucleus of the hypoglossal (supplying the tongue) and that of the seventh nerve (supplying the orbicularis).

(2) The manner in which the muscles are affected in bulbar paralysis points strongly in the same direction. Next to the tongue, the lips usually suffer most. Yet the remaining muscles of the face, supplied as they are by the same nerve as the lip-muscle, are quite unaffected, or but slightly involved. Indeed, the zygomatici, immediate neighbours of the orbicularis, are so well preserved in comparison with the latter, as to cause, by their unopposed contraction, an alteration in the appearance of the face. These facts suggest that those fibres of the facial nerve which supply the orbicularis oris arise in or near the hypoglossal nucleus, and certainly in much closer connection with this than with the proper nucleus of the facial nerve.

3. Although the arguments given under headings 1 and 2 are very strong, and indeed practically conclusive,—so far, at least, as 1 is concerned,—it is obvious that the one thing that is necessary to clench the argument is evidence that a lesion confined to the facial nucleus does not necessarily cause paralysis of the oculo-facial group of muscles or of the orbicularis oris. Evidence of this kind is not altogether wanting.

(1) Gowers mentions (9) a case of facial palsy from nuclear inflammation (part of polio-myelitis), in which the orbicularis oris escaped entirely, though the rest of the face was absolutely paralysed.

(2) A patient of mine, whose case may yet be published in detail, suffers from paralysis of the conjugate movement of the eyeballs to one side. The lesion is probably situated in one sixth nucleus, around which, of course, the seventh nerve winds immediately after leaving its own nucleus. This patient's face appears to be slightly weak on one side, and, so far as can be made out on careful examination, the difference between the two sides is confined to the middle group of muscles (supplied from the seventh nucleus proper); whilst the oculo-facial group (supplied probably from the third nucleus) and the orbicularis oris (supplied probably from the twelfth nucleus) have escaped.

I admit that this case is of small worth in the present argument, except in the way of corroboration; but viewed in this light, it seems to possess a certain value.

Thus, with regard to palsies of the facial nerve, it may be remarked that Bell's paralysis, in which the facial trunk is involved distally to the point where the various component parts are united into one, implies paralysis of all the three sets of facial muscles. Disease of the third nucleus involves the upper facial (oculo-facial) group, and disease of the twelfth nucleus involves the lower facial (ori-facial) muscle; whilst disease confined to the seventh nucleus involves only the mid-facial group.

Two instances, then, have been adduced, in which nuclei belonging to the anterior cranial group (third and twelfth) send out fibres by a nerve-root (seventh) which belongs to the lateral group. This is the converse of what obtains in the spinal cord, where (except in the cervical region) fibres from the cells of the lateral horn issue along with those from the anterior horn proper by roots belonging to the anterior series.

SUMMARY.

Even those cranial nerves which, under Dr Hill's scheme of a four-root grouping, the neurologist might with the greatest

confidence expect to find issuing from the cerebro-spinal axis in a state of purity (*i.e.*, composed of elements derived from one only of the four roots), are discovered, on more careful investigation, to contain a considerable admixture of foreign elements. We must therefore keep in view the possibility that careful clinical observation and pathological anatomy will ultimately show that not one of the cranial nerves can be considered unmixed in its composition.

I shall conclude by mentioning Professor Sherrington's observation that all macroscopic nerve-trunks, including all that have hitherto been supposed to be purely motor, such as the hypoglossal and phrenic, contain sensory nerve-fibres (10).

REFERENCES.

- (1.) Gaskell, *Jour. of Physiol.*, 1886, vii., and 1889, x. Hill, *Brain*, 1888, x. p. 422. Ross, *ib.*, p. 333.
- (2.) See Hill, *Brain*, *loc. cit.* The illustrative diagrams are reproduced in this author's admirable translation of Professor Obersteiner's work on *The Anatomy of the Central Nervous Organs*, 1890.
- (3.) *Dis. of the Nerv. Syst.*, 2nd ed., ii. 47, note.
- (4.) Obersteiner and Hill, *Anatomy of the Central Nervous Organs*, pp. 309, 310.
- (5.) *Berl. Klin. Woch.*, Nov. 1887, No. 48, SS. 913-916.
- (6.) "Study of a case of Bulbar Paralysis, with notes on the origin of certain cranial nerves," *Brain*, 1891, xiv. pp. 473-495.
- (7.) *Lancet*, 8th April 1893, p. 821.
- (8.) *Ib.*, 15th July 1893, p. 128.
- (9.) *Op. cit.*, ii. 240.
- (10.) *Jour. of Physiol.*, Oct. 1894, xvii. 255.

ON THE OPTIC NERVE AS PART OF THE CENTRAL NERVOUS SYSTEM. By T. K. MONRO, M.A., M.D., F.F.P.S.G., *Assistant Physician to the Royal Infirmary, and Pathologist to the Victoria Infirmary of Glasgow.*

It has long been universally acknowledged that the olfactory and optic nerves (the first and second pairs of Willis and Soemmerring) possess a value and significance which are entirely different from those of the remaining seven pairs of Willis or ten pairs of Soemmerring. The recognition of this fact is due in large measure to embryology, but morphology has, in recent years, been called upon to corroborate the teaching of development.

The same question has long presented itself to physicians and pathologists, who often meet with chronic disease of the spinal cord and of the optic nerves associated in one patient. This is a familiar occurrence; but less common, though still more remarkable, is the simultaneous occurrence of separate and distinct foci of more or less acute inflammation in the optic nerves and in one or several portions of the spinal cord. I have been able to collect published records of twelve cases of this kind. Ophthalmologists, in discussing such facts, draw attention to the circumstance that the optic nerve is different from other nerves, and is in some ways rather to be regarded as part of the central nervous system.

It is the purpose, then, of this paper to suggest that the optic nerves and tracts ought to be frankly recognised as being as much a part of the central system as, for instance, the cerebellum or pineal gland; and further, to show that there is one portion of the central system, viz., the posterior columns of the cord, to which, in particular, the optic nerves or tracts present a very close degree of similarity.

(1) The posterior columns remain throughout life, almost in their entirety, an integral part of the spinal cord. They are

originally formed by the growth of nerve-fibres into the cord from the ganglia of the posterior roots, and these fibres are developed as processes of the cells of these ganglia. The ganglia are formed originally from the same epiblastic cells as the cord itself, through portions of the thickened epiblast being caught by the walls of the medullary groove, as these close to form the central canal of the cord.

The retinae and optic nerves originate from the primary optic vesicles, which are diverticula of the forebrain, and the fibres of the optic nerves and tracts grow inwards from the cells of the retinae towards the cerebrum.¹

Again, both optic nerves and posterior columns consist of fibres which follow the rule (to which peripheral afferent nerves are the only exception) that they grow out of cells in the direction in which they are destined to convey impulses.

(2) When the optic tract is cut across, its two ends will never unite again. This is a character belonging to all central nerve-tracts, and is a contrast to what obtains in the case of peripheral nerves.²

Further, the optic tract resembles in its structure the white matter of the brain, being very soft, and not divided up into bundles by connective tissue, whilst its fibres are not provided with membranous sheaths.³ (This description, however, is not applicable to the chiasm and optic nerves.)

(3) The optic nerves and posterior columns are both afferent in function. They convey impressions, the former from the eyes and the latter from the muscles; and these two are at least as important as any other of the various kinds of afferent impressions (from skin, semicircular canals, &c.) which are co-ordinated by the cerebellum and transmitted to those motor centres in the brain which, by their activity, keep the body in a position of equilibrium. The two sets of fibres, therefore—optic tracts and posterior columns—are closely allied in function.

(4) Both frequently suffer from disease. Either may suffer by itself, and disease of one may ultimately become complicated

¹ Obersteiner, *The Anatomy of the Central Nervous Organs*, translated by Hill, 1890, p. 279; also note by Hill, p. 183.

² Obersteiner, *op. cit.*, p. 279.

³ See *Quain's Anatomy*, 10th ed., 1893, vol. iii. part i. p. 118.

by disease of the other. Such disease frequently takes the form of a chronic degeneration of the nervous elements associated with secondary overgrowth of the interstitial elements.

In the one case, the lesion involves the layer of nerve-cells and the layer of nerve-fibres in the retina, together with the optic nerve and tract as far back as its termination in the pulvinar of the thalamus, the lateral geniculate body and the anterior corpus quadrigeminum.

In the other, the posterior spinal nerve-roots, from their nutritive cells in the posterior root-ganglia to their endings in the nucleus gracilis and the nucleus cuneatus, undergo degeneration.

Such degeneration of nerve-fibres must be regarded as due to changes in their nutritive cells, these changes being at first nutritional, but ultimately, no doubt, in many cases, structural. The fibres tend to degenerate in their whole length, for they probably end, for the most part, in the nuclei mentioned, by dividing and subdividing to take part in the formation of the delicate arborisations which surround the cells of these grey masses, but without ever becoming actually continuous with the cell processes.

(Virchow, in 1856, first showed that only the two inner layers of the retina undergo degeneration in primary optic atrophy.¹)

(5) The special liability of the male sex to suffer, and the age at which they chiefly occur, are characteristics presented in common by primary optic atrophy and posterior sclerosis.

(6) Moreover, when the function of the one set of fibres is impaired by disease, its place is readily filled by the other set. A blind person, like a healthy person in the dark, maintains his equilibrium by means of his muscular sense; so that an ataxic person requires his eyesight if he is to walk with any freedom. I have seen a patient who had suffered from tabes for fourteen years, and was quite unable to stand with feet together and eyes shut. Yet, when one eye was covered, he did not even require to look with the other at his feet or at the floor, but could promptly move it in any direction indicated without the least unsteadiness resulting—so perfectly did the healthy activity of one eye compensate for the abrogated function of the posterior

¹ See Gowers, *Med. Ophthalmoscopy*, 3rd ed., 1890, p. 118.

columns. On the other hand, I have repeatedly been consulted by a patient who has suffered from tabes for years. He is blind from optic atrophy, yet has no trouble about his equilibrium. It was, I believe, Benedikt who first pointed out the remarkable fact that in cases where optic atrophy and posterior sclerosis are associated in one individual, the severity of the one lesion, as manifested by symptoms, is often inversely proportional to that of the other.

The facts, then, when all put together, seem clearly to demonstrate the truth of these two propositions: firstly, that the optic nerves and tracts are truly a part of the central nervous system; and secondly, that there is a particularly close resemblance between the optic nerves and the posterior columns of the cord. If we look upon the optic nerves in this light, it becomes less difficult to understand the simultaneous occurrence of independent lesions, acute or chronic, in the two structures, for similarity in structure and function confers upon tissues a common susceptibility to morbid processes.

THE ORIGIN AND INTRA-CRANIAL COURSE OF THE
OPHTHALMIC ARTERY, AND THE RELATIONSHIP
THEY BEAR TO THE OPTIC NERVE. By EDWARD
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ALTHOUGH this artery, when compared with its parent, is insignificant in size—so much so, as almost to escape notice in the cranial cavity—it has nevertheless a course which is as characteristic in its appearance, as it is remarkable for the constancy with which it exhibits that characteristic appearance.

Origin.—As it is a small artery, its mode of origin needs to be considered with minuteness. In all cases with which I am familiar, the artery arises from the top of the internal carotid artery, that is, from the middle of the upper aspect,—from that part known as the 4th bend.

It is thus a median artery in so far as its origin with reference to the dorsal or upper aspect of the internal carotid is concerned, but the site of origin varies a little in different subjects in the antero-posterior direction, it sometimes being nearer, sometimes further away from the optic foramen, through which it is destined to pass.

This slight variability has an important bearing on the relationship which the artery bears to the optic nerve.

Course.—Having arisen from the internal carotid in the way above mentioned, the ophthalmic artery always passes *forwards* for a short distance—on an average 1 to 2 mm.; then it suddenly bends outwards; after which, proceeding more gradually outwards, it enters the optic foramen.

Relationship with the Optic Nerve.—This is dependent to a considerable extent on the length of the interval between the point of origin of the artery and the margin of the optic foramen. In most cases the origin is so situated as to lie below the middle of the longitudinal axis of the optic nerve, and as

that nerve passes obliquely backwards and inwards towards the chiasma, the artery, which passes straight forwards at first, comes to lie below the *inner* half of it, and, in many cases, where the straightforward course of the artery is somewhat prolonged, it actually appears on the *inner side* of the nerve, after which it gradually passes away to the outer side, so that it comes to lie below the outer half of the nerve at its entrance to the optic foramen.

If this be the normal relationship between the two structures, it is obvious that backward removal of the site of origin of the artery will alter the relationship of the origin and course of the artery to the optic nerve; in fact, the artery will be placed a little to the outer side of the median axis of the nerve, and will not reach so far under the inner half of it as to be visible on its inner side, and will consequently reach the outer side the sooner.

Then, again, if the origin be placed nearer the optic foramen than usual, the artery, provided it pass straightforward for the usual distance, will reach the inner side of the nerve, and be there visible; its appearance on the outer side being correspondingly delayed.

There has been considerable diversity of description of the relationship between artery and nerve, though, with the appearance of later editions of the standard text-books,—which pass over the question by stating that the artery arises below the nerve, and by the smaller works adopting the descriptions of the larger,—more unanimity prevails; but none of them alludes to the intra-cranial course of the artery in detail, which, from its constancy in character, seems to me to deserve more attention than has been given it.

At first I was inclined to think that the inward bend of the ophthalmic artery might be due to the pressure of the optic nerve on it when it was being filled with injection mass; but many subsequent examinations in the post-mortem room have dispelled that idea. Then it occurred to me that the optic nerve might have got dragged backwards, when the brain was lifted up preparatory to its removal from the skull, and that this dragging backwards might make the course of the optic nerve appear to be more directly a backward one than it is; in

fact, I thought that the inward course of the ophthalmic artery might be artificial, not natural; apparent, not real. For three reasons that idea was untenable. First, because when the brain was removed in sections, by dividing it transversely between the Sylvian fissures and turning forward the anterior part, the same relationship was maintained. Second, the internal carotid artery, at the point where it gives off the ophthalmic, is so firmly blended with the fibrous sheath of the optic nerve, that movement of the one cannot take place without movement of the other: they move together.

As a matter of fact, the idea that the optic chiasma lay in a transverse groove on the body of the sphenoid, anterior to the olivary eminence, was so firmly rooted in my mind by orthodoxy, in spite of experience to the contrary, that I hesitated to advance the contrary as a third reason for the untenability of my theory that the optic nerve must have been disturbed in some way.

Any doubts, however, that I had as to the accuracy of the generally accepted position of the optic chiasma and the optic nerve were dispelled by some remarks made by Mr T. W. P. Lawrence in the *Proceedings of Anatomical Society* (May 1894), for he here remarks that "in some recently observed specimens the commonly accepted position of the commissure upon the optic groove was departed from; and although the number of cases examined was too small to justify the statement that the commissure never lies upon the optic groove, he believed that such will be found to be the case." That opinion I am glad to confirm, though my own observations extend back to the year 1891.

It is obvious that the dispulsion of this idea as to the necessarily nearly transverse direction of the optic chiasma has a most important bearing on the relationship between the ophthalmic artery and the optic nerve; for if that nerve were almost transverse, as it would of necessity be were the chiasma actually placed in the groove, it would have been practically impossible for the ophthalmic artery to reach the inner side of the optic nerve in its course forwards to the optic foramen.

This false general impression just alluded to seems to me to be the key to the whole position, and seems to explain the

inaccuracy of the older works on Anatomy which—*Gray*, for example, 12th edition, page 518—state that “the ophthalmic artery arises from the internal carotid just as that vessel is emerging from the cavernous sinus and enters the orbit through the optic foramen below, and to the outer side of the optic nerve;” and in the accompanying figure (fig. 338), in the work above mentioned, the optic chiasma is represented as lying in the optic groove, and the ophthalmic artery is visible in its whole course on the outer side of the nerve; and what is more, it proceeds straight outwards from its origin to the optic foramen, a condition I have never observed. In the *Journal of Anatomy and Physiology* for 1893, pages 280–1, Dr James Musgrove describes an ophthalmic artery which arose from the middle meningeal, and which, having reached the optic nerve after having entered the orbit through the sphenoidal fissure, gave backwards a fibrous cord which ended at the internal carotid artery.

Commenting on this fibrous cord, at the end of his communication, Dr Musgrove says “that the fibrous cord, which no doubt represents the original ophthalmic artery, was found on both sides at the *inner*—(the italics are mine)—part of the optic foramen, as though the artery had passed to the orbit at the inner instead of the outer side of the optic nerve.”

This commentary I regard as extremely valuable, because it bears out my statements unconsciously, and at the same time demonstrates how far actual observation may be overruled by well-cherished ideas, as it was in my own case.

THE RETINACULA OF WEITBRECHT. WHAT IS
THEIR FUNCTION? By EDWARD FAWCETT, M.B.
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It is well known that when the capsule of the hip-joint is laid open from the front, it appears to be reflected from its femoral attachment along certain lines to the margin of the articular surface of the head of that bone. It may not be so well known that these bands are called the Retinacula of Weitbrecht. The historical interest in these bands was suggested to me by the addition of Weitbrecht's name as made in Macalister's "*Text-book of Human Anatomy*," which states (p. 179) that "from the femoral attachment of the capsule, strong flat reflected bands pass towards the margin of the head of the bone lying on the neck: one strong band passes inwards and backwards from the tuberculum colli superius, a second from the tuberculum colli inferius, and a third from the vicinity of the lesser trochanter. These are called the *retinacula* of *Weitbrecht*. In Cunningham's "*Manual of Anatomy*," 1893, p. 262, they are alluded to in a footnote as the cervical ligaments of Stanley.

They first received attention at the hands of Jos. Weitbrecht, who describes them in his work on *Syndesmologie*.

In the adult these retinacula may be said to be normally three in number, and may be termed, from their relative positions, upper, middle, and lower.

The upper band passes from the tuberculum colli superius along the upper and anterior margin of the neck of the femur as far as the articular cartilage, but before reaching that cartilage it becomes firmly blended with the neck of the femur, causing, in the majority of cases, a rough tubercle, or it may be a ridge, which extends downwards parallel with the anterior intertrochanteric line, and lying almost midway between it and the articular margin of the head.

The middle band passes from the tuberculum colli inferius to the head of the femur, practically parallel with the last.

The lower band, arising from the neck just above the small trochanter, is continued along the lower border of the neck of the femur to the margin of the head.

The middle and lower bands are generally indissolubly blended with the periosteum of the neck of the femur.

The upper band may be free as far as the tubercle or ridge on the neck above alluded to.

Function.—So far as I know, they are generally regarded as splints in some cases of intra-capsular fracture of the neck of the femur.

In the footnote before alluded to in Cunningham's *Manual of Anatomy*, we find that "in intra-capsular fracture of the neck of the femur they may escape rupture, and they then form a sort of natural splint which retains the fragments in apposition. Hence examinations of this class of fracture must be gently conducted, lest by rupturing this ligamentous connection the fragments be permanently displaced."

This statement may be taken as the sum of the averages of statements made by the various works on Surgery.

It is indeed fortunate that nature has provided us with a means of bringing about a good result in some cases of fracture of the neck of the femur—a result which is unfortunately rare in those people most liable to it; but I would go further, and suggest that nature has provided us with a means of preventing fracture at a time of life when, by virtue of our own want of thought, there is most necessity for it.

I must first introduce my theory by asking the following questions:—Why should these retinacula pass as far as the cartilage-clad head of the femur, and why should they be arranged in such definite positions, viz., at the upper and lower margins of the neck of the femur? Not, surely, because they are to be of use when the bone only is broken, for then any position would have served; and besides that, a better result would have been obtained if the periosteum itself had been thickened all round the neck of the femur. Does not their definitely allotted position rather point to their being of use in limiting excessive strain in certain directions?

What we know of the arrangement of ligaments in the ordinary chondroarthrosis (amphiarthrosis) suggests that they

have arisen hereditarily by strain or pressure exerted in a constant and dangerous direction, or become specialised as a result of that pressure?

We know that the head of the femur, after the third year, at least, is united to the neck by a plate of cartilage, which makes this junction a hyalo-chondrosis till the eighteenth year; we know, moreover, in the case of bones united permanently by a plate of cartilage, that their respective investments of periosteum and perichondrium become specialised in directions corresponding to dangerous and common strains—for example, the anterior and posterior common ligaments of the vertebral column; and I think it is not unnatural to suppose that strain put upon the epiphysial cartilage between the neck and head of the femur would be at certain times excessive and dangerous; greater, in fact, than mere union by cartilage and a comparatively lax capsular ligament could resist. We are therefore, I think, justified in looking to these retinacula as being means to prevent tearing of the head of the femur from the neck of that bone, and we may advance three reasons in support of this view:—in the first place, the constant, definite position of these bands is suggestive; in the second place, the fact that these bands are placed at the upper and lower parts of the neck of the femur, I think, points to some definite purpose; and thirdly, an appeal to the condition of the retinacula in the young joint affords perhaps the strongest evidence of all.

Taking the first of these reasons first, it is evident that definiteness of position indicates definiteness of strain; the second reason points to dangerous strain acting in a certain definite direction; and because these retinacula are chiefly placed at the upper and lower borders of the neck of the femur, we would infer that the strain was one coming from above or below. As the femur is the first osseous structure that has to bear the weight of the body in walking, we may take it for granted that the chief strain is a downward one, and for this reason we deduce that the retinacula ought to be placed above and below: above, alone, they would not do, as such an arrangement would simply act as a fulcrum on which to work, and the wound, if started, would gape below; and an appeal to the state in the new-born child confirms the third reason. In the new-

born child the retinacula are well developed,—much more so relatively than in the adult,—and, unlike those of the adult, are placed in *two* positions only, namely, above and below the neck of the femur. The primary intention here is evidently that of resisting the weight of the body when the child afterwards commences to walk.

But it may be asked why these retinacula occupy only two positions; why a third band is not placed in front and below, as in later conditions? The answer is given in the study of the attitude and gait of the child on its early attempts at walking. In a child, the natural position of the leg is that of inversion—the great toe is turned inwards naturally, both when at rest and when walking; the outward direction of the toes is a condition acquired later in life, and is a result of the more erect attitude attained by the adult and by the higher races of mankind.

With the toes turned inwards the head of the femur is correspondingly directed more backwards; in other words, the strain or pressure of the body-weight is directed more vertically than in the adolescent period and in later life. As the adult condition is approached, the toes become turned outwards in walking; the head of the femur, as a consequence, becomes less buried in the acetabulum than it was in the child; the centre of gravity falls behind the axis of rotation of the femur, and the new direction of the neck of that bone, if prolonged from the head to the centre of the acetabulum, forms an obtuse angle in front of the base formed by the original axis, and, as a consequence, the strain or body-pressure no longer acts in a vertical direction, but is directed downwards and forwards, and so tends to drive the head of the femur downwards and forwards. In consequence of this, a specialisation—may we say, shifting—of part of the lower band takes place, and forms a third, the one described as the middle band, which in the adult stretches between the tuberculum colli inferius and the articular margin of the head of the femur.

The hip-joint of the child forms an interesting object of study. Not the least interesting and important is the fact that, till walking is firmly established, it is always in a state of flexion, a condition brought about by several factors,—anatomically,

however, by two, viz., shortness of the anterior part of the capsule and tension of the ilio-psoas tendon, both of which maintain the joint in the semi-flexed state. Physiologically this naturally flexed state is one which has its origin *in utero*; and as there is then little use for the extension of the hip-joint, the constant attitude of flexion does not demand great length of the anterior part of the capsule of the joint, for the capsule of any joint is never at any time longer than the range of movement permitted by the tonicity of muscles which cross it; in other words, the length of the capsule is directly proportionate to the range of movement allowed at the joint; and because this is the case, the anterior part of the capsule of the hip-joint, over-extension, which it is intended to prevent, being in abeyance,—and the joint till the child commences to walk is always in a state of flexion,—is short, and becomes lengthened out in proportion as the increasing demands of the maintenance of the erect attitude require.

So long, therefore, as the hip-joint is normally in a flexed condition, so long do we expect to find the retinacula placed in two sites, because they have to meet a more or less vertical strain; then, as the erect attitude, which is accompanied by over-extension of the hip-joint, calls forth a new strain, we expect a new resistance, and we find it in the third retinaculum.

I think I am therefore warranted in advancing the theory that the main object of the retinacula of Weitbrecht is not to afford a natural splint to a fractured cervix femoris, but to form buttresses which may prevent such accidents happening, and chiefly at a time when, as before said, by virtue of want of care for our limbs, we tax the strength of our hip-joints to the utmost,—the period when the epiphysial cartilage forms the direct bond of union between the head and neck of the femur,—in other words, the period of youth; and in the possession of these retinacula the epiphysio-diaphysial joint at the neck of the femur is only brought into conformity with other joints of the class to which it belongs, namely, the class Chondroarthrosis (Amphiarthrosis).

That the retinacula are placed in the position of greatest strain is also borne out by the fact that we find them also in the shoulder-joint, where they are placed, as in the hip-joint, at the

point where the capsular ligament is longest in the shoulder-joint, on the under aspect of the neck. In this joint, protection is chiefly afforded by muscles; and they are, with the exception of the long head of the triceps, placed above, in front of, or behind the joint, and consequently the action of them alone in raising the segment beyond the epiphysial cartilage is enough to warrant the placing of a tie-beam under the neck, to prevent too great strain on the cartilage during raising of the arm.

LYMPHADENOMA (HODGKIN'S DISEASE) OF THE
LYMPHATIC GLANDS AS A DISTINCT PATHO-
LOGICAL AFFECTION. By GORDON SHARP, M.B. Edin.,
*late Research Student in Pharmacology, Owens College,
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So much diversity of opinion exists among authorities, as to the true nature of the pathological change in the lymphatic glands in this affection, that one is hardly safe in saying there is any definite disease answering to that described by Hodgkin in the year 1832 (No. 34, xvii), supposing we are to judge from macroscopic and microscopic appearances only.

Hodgkin's disease is named *lymphoma* by Ziegler, *adenia* by Trousseau, while British pathologists variously class together strumous glands, lymphadenoma, lymphoma, and lymphosarcoma, some believing them to be one and the same, or nearly related, while others make distinctions of a more or less definite character. Payne (*Manual of General Pathology*) says:—"No distinct line can be drawn between these productions and lymphosarcoma. The name lymphadenoma has also been used, but in practice means the same as lymphoma." Hamilton (*Text-book of Pathology*) is more cautious, saying:—"The affection looks more like a lymphadenitis due to some wide-spread cause than a disease of a truly sarcomatous nature." Coates (*Manual of General Pathology*) speaks as follows:—"Chronic lymphadenitis.—This term might be made to include a number of conditions which will be afterwards referred to as occurring in leukæmia, Hodgkin's disease, &c., as well as in scrofulous disease of the glands." Boyce (*Text-book of Morbid Histology*) describes the microscopic characters of what he evidently believes to be a distinct disease. "Sections of soft tumours consist almost entirely of small lymphoid cells, with some epithelial cells, and of a reticulate stroma. In a section of a hard tumour, whilst there are numerous small cells at the periphery or scattered in groups, there is at the same time a very universal increase of the reticulate frame-work." Steven (*Glasgow Medical Journal*) speaks of Hodgkin's disease as a hyperplasia of the blood-forming organs with metastatic deposits in the various organs. Dreschfeld (*Brit. Med. Jour.*, April 30, 1892) looks upon Hodgkin's disease as including lymphoma, lymphadenoma, and lymphosarcoma, saying:—"I therefore look upon the malignant lymphoma, including lymphadenoma and lymphosarcoma, as a specific inflammatory growth, due to a specific infective agent." Woodhead (*Text-book of Practical Pathology*) speaks

with no uncertain sound, and gives the characteristic features of lymphoma, lymphosarcoma, and lymphadenoma as follows:—

“Lymphoma—ordinary lymphoid tissue; both endothelial plates and reticulum well developed; number of lymphoid cells normal.”

“Lymphosarcoma—small number of endothelial plates, correspondingly scanty reticulum; enormous increase in the number of lymphoid cells.”

“Lymphadenoma—early increase in the number and activity of the endothelial plates, accompanied by increase of reticulum, which leads to a great diminution of lymphoid cells.”

The description given by Woodhead corresponds with my experience of the affection generally known by the name of Hodgkin's disease, or lymphadenoma, as it attacks the lymphatic glands. This experience has been gained clinically as well as by the examination of naked-eye and microscopic specimens in the same patients. Clinically, physicians appear to have little difficulty in diagnosing a case of Hodgkin's disease, from the enlargement of the glands, the presence of more or less anæmia, and the beneficial effect of large and continued doses of arsenic. If, from a patient with this clinical history, we remove the affected lymphatic glands, and cut into them, we find in almost every instance an absence of suppurating points; further, we find the gland to be made up of a series of more or less round bodies of a pale pink or white colour, surrounded in recent cases by a thin narrow ring of different coloured tissue, while in more advanced cases this ring is much broader. If a specimen be mounted in gelatine, the cut section shows the condition very clearly. The fibrous tissue is seen invading the proper gland structure, and cutting off islands of various sizes, and all more or less round in shape. From the difference in size, both of the gland tissue and of the fibrous material, the cut surface of the gland presents a worm-eaten appearance. So striking is the difference between the two tissues, that when one comes to make a photograph of the section, the various points are readily reproduced.

On the other hand, a mass of glands, strumous in nature, and which has existed for even a month or two, shows suppurating or caseous points, or both; and on closer examination, one finds none of the roundish masses found in Hodgkin's disease: the appearance is that of masses of glands enlarged variously, and matted together, and without any evident internal growth.

When we come to compare lymphadenoma (Hodgkin's disease) with lymphosarcoma, we find there is a wide difference between them. In lymphosarcoma we have a mass more globular in appearance, and more often being in one single mass. On section, we miss the roundish masses, but scattered throughout points of hæmorrhage are seen, never found in true lymphadenoma. The whole tumour has a softness about it, as if the stroma was too meagre for the intercellular elements, but this point is more apparent when the microscopic characters come to be examined.

When one examines microscopically a gland which, from the clinical symptoms, permits no doubt as to its strumous nature, we find—setting aside the consideration of the suppurating and caseous centres—an aggregation of small round cells (with or without the characteristic foci), and a small amount of fibrous tissue. The fibrous tissue is scattered throughout the section in equal proportions, and, however long the condition may have lasted, is never a marked feature. These points can be clearly demonstrated from microphotographs of sections.

On the other hand, a gland from a case of Hodgkin's disease (lymphadenoma) presents on examination by the microscope well-marked features. In addition to the cellular changes, we find a distinct growth of fibrous tissue, not distributed regularly throughout the gland as in strumous glands, but in very evident strands, which appear first at the periphery and slowly advance towards the centre, till finally the proper gland tissue is displaced, and only a mass of fibrous tissue remains. By making a series of microphotographs and comparing with the strumous change, the difference between the two conditions can be readily seen and appreciated.

Lymphosarcoma differs materially from both the foregoing. Instead of the final change being a fibrous one, as in lymphadenoma, it is a cellular growth, and the microscope shows an enormous collection of round or other cells, with a disproportionate amount of fibrous tissue. The growth of cells goes on, but in some parts one may fail to detect any fibrous tissue. These features, too, can be observed in microphotographs.

It will thus be seen that careful examination by the naked eye and by the microscope enables us to mark out the various

morbid conditions which are so often confounded with one another.

It is interesting to trace the natural history of the various diseases already named. In tubercular glands we have an irritating agent in the shape of a specific micro-organism, which multiplies itself, and causes a growth of all the glandular elements at first, but subsequently causes death of the gland tissue. Tracing lymphosarcoma and lymphadenoma as they affect the lymphatic glands, we find that we have an unknown irritating agent, and that, broadly speaking, both tumours start from a *lymphoma*. If the further growth of the tumour is characterised by the presence of enormous numbers of round cells, with a small amount of fibrous tissue and endothelial plates, then we get a *lymphosarcoma*. On the other hand, if the tumour growth tends towards the formation of fibrous tissue, with a sparing amount of the cellular elements, then we have *lymphadenoma*, or the so-called Hodgkin's disease.

THE NERVE OF WRISBERG. By A. BIRMINGHAM, M.D.,
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IRREGULARITIES in size, and absence, of the lesser internal cutaneous or nerve of Wrisberg, as well as the relation which its development bears to that of the intercosto-humeral, are well known and oft noted facts. But I am not acquainted with any record of a relation, which I am satisfied exists, between the nerve of Wrisberg and the first dorsal; namely, when the former is absent as a branch of the brachial plexus its place is taken, generally if not always, by a lateral cutaneous branch of the first dorsal nerve.

In illustration of this, I have notes of six cases in which the condition mentioned obtained. In each of these the cords of the brachial plexus failed to give off a nerve of Wrisberg, while a nerve with a similar distribution arose from the first (receiving as a rule also fibres from the second) dorsal, it then pierced the first intercostal space, and, appearing to be to all intents and purposes a lateral cutaneous of the first intercostal, occupied, a little lower down, the position usually occupied by the lesser internal cutaneous. In other words, the normal nerve of Wrisberg was absent, and its place was taken by a lateral cutaneous of the first dorsal, which was, I have no doubt, merely a displaced lesser internal cutaneous.

The first three specimens were not examined as fully as those found subsequently. In each of the latter a more careful dissection was made, the communicating branch between the first and second dorsal, described in this *Journal*¹ by Professor Cunningham, was carefully examined, and its relation to the lateral cutaneous of the first dorsal made out. In the earlier cases this was not done. The details of the six specimens are as follows:—

In the three first found, I merely ascertained that the nerve of Wrisberg was absent as a branch of the brachial plexus, that its place was taken by a lateral cutaneous piercing the first

¹ Vol. xi. p. 539.

intercostal space, and finally that this lateral cutaneous arose from the first dorsal nerve; in one specimen coming off—from

Fig 1



a, First intercostal nerve; *b1*, *b2*, *b3*, shows irregular origin of nerve of Wrisberg in first three cases.

the trunk which joins the brachial plexus—high up while crossing the neck of the first rib, in a second at a lower level and in a third low down, quite close to the point at which the main trunk is separated from the first intercostal. These three positions are shown in fig. 1 as *b1*, *b2*, and *b3*.

The arrangement in the fourth specimen is shown in fig. 2, in

Fig 2



a.a, Intercostal part of first dorsal; *b*, lateral cutaneous of first dorsal;
c, branch from 2nd to 1st dorsal; *d*, 2nd intercostal.

which, as in the following figures, *a* represents the intercostal parts of the first dorsal, *b* the lateral cutaneous of the same

nerve, *c* the communicating branch from the second to the first dorsal, and *d* the second intercostal. In this specimen the first dorsal divided into a larger trunk which passed up to join the brachial plexus, and a smaller which soon divided into three; two of these, *a a*, were distributed in the intercostal space; the third received the communicating branch from the second dorsal, passed along the first intercostal space, pierced the intercostal muscles, and reaching the axilla was distributed as the nerve of Wrisberg.

In the fifth specimen, fig. 3, nearly the whole of the first dorsal passed up to the brachial plexus, only a very small

b

Fig 3



a, Intercostal part of 1st dorsal; *b*, lateral cutaneous part of 1st dorsal;
c, branch from 2nd to 1st dorsal; *d*, 2nd intercostal.

portion running out to the intercostal space; this latter was joined by a much larger branch from the second dorsal, *c*; after a short course the resulting trunk divided into an intercostal part, *a*, and a lateral cutaneous part, *b*, which pierced the intercostal muscles and was distributed as in the preceding case.

In the sixth specimen (fig. 4) the arrangement differed little from that shown in the fifth. Here, however, the branch from the second dorsal, *c*, which was small, divided into two as it approached the intercostal part of the first; in similar fashion the latter divided, as in No. 5, into an intercostal proper and a lateral cutaneous, each of which was joined by one of the divisions of the communicating branch from the second dorsal, so that the second contributed not only to the formation of the

lateral cutaneous of the first dorsal (that is, the representative of the nerve of Wrisberg), but also, by joining the intercostal part proper of the first dorsal, helped to supply the first intercostal

Fig 4.



Reference as in Fig. 3.

space,—a state of things to which there would seem to be a tendency, as shown on the opposite side of the subject, from which the fifth specimen, described above, was taken. In this, as shown in fig. 5, the first dorsal gave off a very small inter-

Fig 5.



a, First intercostal ; *c*, branch from 2nd intercostal to first space ; *d*, and *e*, rest of intercostal going to 2nd space.

costal branch, *a* ; the second dorsal gave off a small branch, *e*, to the hinder part of its space, then crossing the second rib

obliquely, ran along the lower part of the first space, gave off a branch to the first space, *c*, and recrossing the second rib was continued out in its own space, *d*. That is to say, the second intercostal supplied, at a considerable distance from the vertebral column, a good-sized branch to the first space. It should be added, that in this particular case the communicating branch between the first and second dorsal was entirely absent. Cunningham pointed out that this communicating branch from the second dorsal may join either the brachial or the intercostal part of the first, or both of these.

The above is simply a record of the facts observed in these cases. We must next consider the proper interpretation of these facts. In the first place, it seems reasonable to conclude that the normal nerve of Wrisberg is the lateral cutaneous of the first intercostal nerve, carried up and distributed by the brachial plexus. This for the following reasons:—(1) The nerve of Wrisberg is found to be composed, in the majority of cases, of fibres of the first and possibly of the second dorsal, the latter easily explained through the communicating branch. (2) The distribution of the nerve, in relation to that of the intercosto-humeral, is, as tested by the laws enunciated by Heringham, that of a first dorsal lateral cutaneous. (3) As shown in the cases recorded above, when the nerve of Wrisberg does not arise in the usual fashion from the inner cord of the brachial plexus, it is represented by, or becomes, the lateral cutaneous of the first dorsal; being in such cases in what would appear to be its true morphological position. (4) And finally, in the cases recorded above, the nerve which represents the nerve of Wrisberg was found arising practically in every position between the origin of a normal lesser internal cutaneous, and the origin of a typical first dorsal lateral cutaneous.

For these reasons I have come to the conclusion that the nerve of Wrisberg is morphologically the lateral cutaneous of the first dorsal nerve.

Then, if the nerve of Wrisberg represents the lateral element of the first dorsal nerve, what is the nature of the fibres of this nerve which go to join the brachial plexus? This naturally leads to another question,—What is the morphology of the nerves passing into the limb plexuses? As is well known, two different

views are held on this subject. Many anatomists, following Goodsir,¹ consider that these plexuses are formed of the lateral elements of the nerves only, while the ventral portions are in great part or entirely suppressed. On the other hand, Paterson, Eisler, and others maintain that the nerves of the limb plexuses represent both the ventral and lateral division of the ordinary typical segmental nerves. In support of this view, Paterson² pointed out the fact that the anterior primary division of each nerve joining a limb plexus (excepting, as a rule, that of the first dorsal) divides into a dorsal and a ventral branch: the former, he considers, represents the lateral element of a typical segmental nerve (*e.g.*, lateral cutaneous of an intercostal); and the latter, the ventral part of such a nerve (intercostal beyond the origin of the lateral cutaneous).

If it be conceded then that the nerve of Wrisberg is the lateral cutaneous of the first dorsal, it will be interesting to examine the bearing of such a conclusion on our views of the morphology of the limb plexuses. This brings us back to the question of the nature of the fibres passing from the first dorsal to the brachial plexus. In my opinion, these fibres are wholly or chiefly composed of ventral elements. I have arrived at this conclusion from a consideration of the following points. In considering them, it will be well, for clearness, to keep before us an arrangement of the nerve of Wrisberg such as I have described in the foregoing six cases. (1) The lateral element of the first dorsal in each of these cases was distinctly present, and I believe fully represented, in the branch which pierced the first intercostal space and took the place of the nerve of Wrisberg. (2) It would appear that the ventral element of the first dorsal is not fully represented by the first intercostal nerve, for, as a rule, this nerve supplies no anterior cutaneous branch. (3) The portion of the first dorsal which passes up over the first rib does not divide into ventral and dorsal branches like other limb plexus nerves, but remains undivided, and joins with the *ventral* (not the dorsal) divisions of the other nerves entering the plexus. These facts, to me, seem to point clearly to the conclusion in the six cases recorded above, that the portion of the first dorsal passing over the neck

¹ Goodsir, *Anatom. Mem.*, vol. ii. p. 201.

² Paterson, *Jour. of Anat. and Phys.*, vol. xxi. p. 629.

of the first rib is made up chiefly or entirely of ventral elements ; and that, in ordinary cases—those in which the nerve of Wrisberg arises normally—the contribution from the first dorsal to the plexus is composed of both ventral and lateral elements, the latter being represented by the fibres of the nerve of Wrisberg. And although the portion of the first dorsal which joins the brachial plexus is said not to divide into dorsal and ventral portions as a rule, still, if we consider the nerve of Wrisberg to be a dorsal (or lateral) branch, we may revise this description, and allow the first dorsal to take its place with the other limb plexus nerves, all of which divide into ventral and dorsal branches.

From the foregoing, it will appear that my reading of the abnormal cases cited above, and the view of the nature of the nerve of Wrisberg, and of the part of the first dorsal going to the brachial plexus, deduced from them, favour Paterson's theory of the morphology of the limb plexuses. For if it be admitted that the nerve of Wrisberg represents the lateral cutaneous of the first dorsal, then the rest of that nerve going to the plexus must be made up of ventral elements, and consequently, ventral (as well as lateral) elements enter into the formation of the plexus.

The only other point worthy of note in these cases is the indistinct demarcation exhibited between the first and second dorsal nerves, as in many other parts of the nervous system. Whether the variations in this regard are due to a wandering in the cord of the cells with which the fibres are connected, or to the fibres following different paths in their course from the cells, it is difficult to say.

ON THE ORGAN OF JACOBSON IN THE MONOTREMATA. By R. BROOM, M.B., C.M., B.Sc. (PLATE II.)

THE organ of Jacobson has of late years received a considerable amount of attention ; and yet, in the way of its comparative anatomy, much remains to be done. As is well known, this peculiar organ is a characteristic of the Mammalia, and among Reptiles of the Lacertilia and Ophidia. Among the mammals it is usually present as a more or less developed organ, though not infrequently it is quite rudimentary, as in Man, or even entirely absent, as in Pteropus ; while it appears to be always well developed among the lizards and snakes. In other groups of reptiles it seems to be generally absent, though, according to Prof. G. B. Howes (1), there is reason to believe that it exists in the Caiman, and I think it not improbable that its presence may yet be detected in some other reptiles. Among amphibians, Prof. Wiedersheim (6) discovered the organ of Jacobson in the highly developed group — the Gymnophiona. In the Monotremata its condition is specially interesting, on account of the reptilian affinities of these low mammals.

Prof. Symington (2) has figured and briefly described the condition of the organ in Ornithorhynchus, and its relations have been more fully dealt with in papers by Prof. J. T. Wilson (3) (4) and Dr C. J. Martin (3) ; while the condition in Echidna has been recently referred to by Prof. W. Newton Parker (5). In my present paper I shall endeavour to supplement Symington's researches on the Platypus, and, from a detailed examination in the Echidna, to institute a comparison between the structure and relations of the organ in the two monotremes, and also to point out some of its reptilian and mammalian affinities.

In his paper on Ornithorhynchus already referred to, Symington calls attention to the reptilian characters of the organ in that genus, such as the great development, the turbinal process, and the forward as well as backward extension of the organ

from the naso-palatine foramen. While such characters are undoubtedly met with in the *Platypus*, they are not all, as will be shown later on, such as are characteristic of the order Monotremata. In *Ornithorhynchus* we have a unique development of the beak, and especially of the prenasal structures (well illustrated by Wilson and Martin (3), a development which is certainly not a reptilian characteristic, and it is probable that the peculiar development of the organ in this genus may, in part at least, be associated with the corresponding development of the prenasal structures.

THE ORGAN OF JACOBSON AND ITS RELATIONS IN ECHIDNA.

Before dealing with Jacobson's organ itself, it will be well to consider briefly the cartilaginous structures related to it.

In *Echidna* the nasal septum passes beyond the nostrils to the very front of the "beak," where it is present as a cartilaginous pad between the two anterior ends of the premaxillaries, and preventing their uniting by a bony suture, as in most of the higher mammals. A little behind this, where the premaxillary bones begin to diverge, this "rostral" cartilage is seen to be broadened out at its base by the addition of the forward extension of the "palatal" cartilages.

In the region of the nostril a well formed septum is met, with short alinasal cartilages, but giving off remarkable alinasal turbinals, which bear a very close resemblance to those in the common chick (fig. 1).

On the plain of the hinder border of the anterior narial opening we find the septum at its base distinct from the two lateral cartilages, which pass outwards from it and form the floor of the inner part of the nasal cavity. These cartilages are most probably developments of the trabecular cornua, but for convenience may be referred to as the "palatal" cartilages. The alinasal turbinal is here well developed, and to the outer side of the nostril is a small detached piece of the alinasal, recalling the cartilage on the outer wall of the nostril in *Ornithorhynchus*.

Passing backwards, we find the palatal cartilages becoming hollowed out near their middle on the under side, to accom-

moderate the extreme anterior end of Jacobson's organ. On this plane also the alinasal cartilage from the septum is seen united with the small detached piece previously mentioned. From this outer portion there arises a peculiar little lamella, which is reflected back towards the upper part of the septum (fig. 2).

In the next stage backwards we find the palatal cartilages each divided by the upward extension of the naso-palatine canal. The inner moiety is roughly cubical in shape, with the outer side concave; in which concavity lies the anterior end of Jacobson's organ, as it opens into the naso-palatine canal. The outer moiety is found as a small plate of cartilage in the nasal floor just outside the canal (fig. 3).

Immediately behind this plane, the inner moiety of each palatal cartilage, now becoming the cartilaginous framework of Jacobson's organ, is considerably increased in size, and resembles the letter "C," with the wall considerably thickened at the upper and inner angle. In the hollow the anterior part of the organ is still seen connected with the naso-palatine canal, which here communicates freely with the nasal cavity. While the naso-palatine canal opens into both Jacobson's organ and the nasal cavity, the connection with the former is rather more anterior than its opening into the nasal cavity, so that Jacobson's organ will be seen to communicate only indirectly with the nasal cavity. On this plane the organ is lined with squamous epithelium (fig. 4 and fig. 5).

Almost immediately behind this the cartilage of Jacobson's organ, "C"-shaped before, is found much expanded, and now in the form of a complete oval ring. Enclosed we find the organ here in almost every respect typically mammalian. The inner and upper wall of the cartilaginous ring supports the typical sensory mucous membrane, while on the lower and outer wall a large development of glandular and vascular tissue forces the mucous membrane of Jacobson's organ inwards, bringing the outer wall almost in contact with the inner, and giving the organ here, on section, the appearance of a gastrula. The epithelial layer on the outer side is about half the thickness of the inner (fig. 6).

As we proceed backwards, the chief difference we meet with in the structure of the organ is that glandular and vascular

tissue becomes supported by a plate of cartilage which passes from the outer wall half way into the cartilaginous tube. This turbinal cartilage, though well marked at the part where the development of the organ is greatest, is absent from both the anterior and posterior quarters of the tube.

The outer moiety of the palatal cartilage, which immediately behind the naso-palatine canal has almost disappeared, on passing backwards soon becomes more developed, and on reaching the plane where the turbinal of Jacobson's organ becomes first well developed passes inwards, and meeting its fellow of the opposite side, the two form a complete transverse plate, on which rest the capsules of the two organs.

At its greatest development, the organ in *Echidna* differs little from that in other mammals where it is well developed, except in the possession of the turbinal plate. This plate is covered, except at its base, by a thick layer of connective tissue, containing numerous glands, and supporting a plexus of large vessels. These vessels appear to run chiefly parallel to the long axis of the organ, so that, on section, seven or eight large vessels are cut across, arranged regularly around the process. The epithelium covering the connective tissue at this part is composed of a layer of large columnar ciliated cells, supported by a layer of small roundish or spindle cells. The connective tissue of the inner wall is a comparatively thin layer, but contains a large quantity of nerve fibres, especially at the upper and lower corners. The epithelial layer is composed of a series of rows of spindle cells supporting columnar cells, with which are intermixed the typical nerve cells. Both the sensory cells and the columnar epithelial cells supporting them appear to be devoid of cilia. About the middle of the thick epithelial layer the spindle cells are unusually large, and have the nuclei chiefly at the lower end. The branched connections of the various cells are very similar to those found in the higher mammals. The glandular ridge outside the organ is in large part occupied by the ducts from the greatly developed glands situated further back (fig. 11).

For a distance of 5 or 6 mm. the organ of Jacobson is practically unaltered, then we find the turbinal process disappear, and the lumen of the organ becomes rapidly contracted. For a

short distance the cartilaginous framework is again, in section, a simple oval ring, containing in the upper two-thirds large bundles of nerve fibres with a few vessels, and in its lower part the tapering posterior end of the organ, surrounded by a little glandular tissue. The organ here is little more than a duct, and is lined with short columnar non-ciliated cells.

A little further back the cartilaginous ring becomes more feebly developed, its upper part first disappearing, and soon only leaving its trace in the firm connective tissue surrounding the nerve bundles. The duct-like extremity of the organ can still be traced a long way back, and appears to be a duct for a considerable part of the glandular tissue behind.

THE ORGAN OF JACOBSON AND ITS RELATIONS IN ORNITHORHYNCHUS.

In Ornithorhynchus, as the organ has been but recently described by Symington (2), I will content myself chiefly with calling attention to a few points supplementing his work, and with pointing out the relation of the parts to those in Echidna.

In a vertical transverse section made a little behind the external nostril in the Platypus we find the framework of the nose very simple (see fig. 1 in Symington's paper)—a thick, short, nasal septum, expanding above into two alinasals, which curve round the nasal cavities, and are continued on to meet each other in the middle line below the base of the septum, against which they abut. There is considerable reason, however, as will be shown later, for regarding the inner half at least of this cartilaginous nasal floor as the homologue of the cartilage in Echidna referred to as the "palatal."

A very short distance behind this plane we find the inner part of the nasal-floor cartilage much enlarged, and excavated by the anterior end of Jacobson's organ, which even here is divided into an upper and lower part by the anterior end of the large turbinal plate passing inwards. This excavation bears only a slight resemblance to the condition in Echidna, but is somewhat similar to what occurs in some Lacertilia, *e.g.* Monitor, and even in some of the higher mammals, as in the Hare. As this

cartilaginous framework of the organ is continued, with only slight alterations, to near the posterior end of the organ, it becomes highly probable that it is really a development of the trabecular cornu that is in contact with the base of the septum, and which has become welded with the large alinasal.

In *Ornithorhynchus* the length of the whole organ Symington gives as 5–6 mm. in his specimen: in the one I have examined, which was a large male, the organ measured about 7 mm. in length, and at its greatest breadth (at the anterior part) 3·8 mm. The organ is naturally divided by the naso-palatine foramen into two sections, which differ considerably in structure (fig. 9).

In the anterior region the organ is broad and flat, and divided into an upper and lower part by a large, straight, turbinal plate, thickened near its inner end. In this anterior region the whole organ is lined with columnar ciliated epithelium. The turbinal process is covered with a vascular plexus, intermixed on the upper side and at the inner end with a few acinous glands. The inner wall of the capsule is lined with a large number of nerves, a few vessels, and a few glands. In this region the epithelial layer is unusually thick, and composed of numerous small cells, covered with ciliated epithelium. I have not as yet investigated the minute histological elements, but this inner wall of the organ in the region of the naso-palatine foramen is probably the chief sensory part.

In the region of the naso-palatine foramen the cartilaginous floor becomes perforated, and the inner part is not again seen attached to the outer in any of the posterior sections. That the portion of cartilage immediately outside the naso-palatine foramen is the homologue of the part similarly situated in *Echidna* may be inferred from the fact that a little behind the foramen it passes inwards and joins its neighbour in the middle line. This median plate is, moreover, quite detached from the alinasals at the sides (fig. 7).

In the region of the foramen, and a little in front, the outer angle of the framework of Jacobson's organ, with the turbinal, is found detached from the cartilage of the nasal floor. Behind the foramen this outer angle joins with the inner part of the cartilaginous floor, forming an irregular tube, which on passing backwards becomes nearly circular, as figured by Symington.

In this posterior region the turbinal process becomes curved downwards, and in section resembles somewhat a bishop's crosier. The sensory layer of epithelium on the inner wall Symington considers in his sections to have been detached, but it is very remarkable that in my sections a similar condition is found, though a little in front the usual sensory epithelium is present. It may possibly be that the epithelium of this part becomes degenerate in the adult, and that the function is performed by the part of the organ near the foramen, and to the front of it.

COMPARATIVE OBSERVATIONS.

In comparing the organ in *Ornithorhynchus* with that in *Echidna*, the most striking difference is seen in the extension of the organ in front of the naso-palatine foramen in the former. This peculiarity may be connected with the unusual development of the cartilages of the beak, though possibly it is one of the numerous reptilian affinities of the genus, as in the *Varanidæ* and other typical lizards the organ at its anterior part excavates the large lateral cartilages. Even in the higher mammals, however, a similar tendency is seen on a small scale, as in the Hare. Another very obvious difference is the unusual shortness of the organ in *Ornithorhynchus* and its length in *Echidna* (fig. 9 and fig. 10).

In mammals, when the organ is well developed, as in the Hare, Goat, Phalanger, Cat, &c., it is usually present as an elongated tube, such as we have in *Echidna*, though occasionally, as in some Bats, it is well developed, and even relatively shorter than in *Ornithorhynchus*.

In the *Platypus* we find the organ supported by the dumb-bell-shaped bone (anterior vomer)—a bone in close association with the capsule of the organ, and of a similar length. In *Echidna* there is no bone supporting the capsule, but there is a mass of firm connective tissue occupying a similar position to the bone in *Ornithorhynchus*; from this and from the vomer proper, only beginning, as in the *Platypus*, at the posterior end of the organ, it is highly probable that in the immediate ancestors of the *Echidna* there existed an anterior vomer.

In both Monotremes the organ is completely surrounded by cartilage, except in the neighbourhood of the naso-palatine foramen. This is not a reptilian character, as in both lizards and snakes the septo-maxillary forms the greater part of the framework above. In Snakes, in fact, there is practically no cartilaginous capsule at all. In many of the higher mammals the organ is completely invested with cartilage, at least for a part of its length, *e.g.*, Cat, Hare, &c.; in others the organ is supported by cartilage only on its inner and under side, *e.g.*, Phalanger, Dasyurus, &c.

The existence of the turbinal process in the organ in Monotremes is a point of peculiar interest, as no similar process has been detected in any higher mammal, and as it recalls the turbinal process of the organ in Lizards as pointed out by Symington. Though the organ is clearly not a near relative of that in the Lizards, there is considerable affinity between the organ in Ornithorhynchus and that in the Agamidæ and the Geckonidæ. A transverse section in the organ in a ripe embryo of Gecko indeed bears a very close resemblance to the section through the organ in the Platypus in the region of the naso-palatine foramen (figs. 7 and 8). In the Monitor, where the organ probably attains its greatest degree of development, the arrangement of parts is considerably more complicated.

Symington expresses a belief that the organ of Jacobson attains its greatest development in the Monotremata, but with this I cannot agree, as in the Monitor it is relatively very much larger, and even among the higher mammals it attains a greater proportional development in some bats.

In the adjoining plan the relations of the organ in the Monotremata are contrasted with those in some typical groups of reptiles and mammals. In each group the characters are taken of some species in which the organ attains a considerable degree of development. In the first two columns the condition of the bony framework is comparatively considered. I have assumed that the palatine process of the premaxillary in mammals is the exact homologue of the "vomer" in lizards, or at least of that part of it in the neighbourhood of the organ, and is properly the anterior vomer. This point might be argued at some length, but, as the result of very considerable independent research, I am

satisfied it is so; the investigations of Howes (1) and Wilson (4) both point in the same direction. My views on this subject I may communicate later in detail. In almost all mammals possessed of an organ of Jacobson this bone is well developed, and developed longitudinally in proportion to the organ. Echidna is the most striking exception. This anterior vomer is generally developed on the inner and under sides of the cartilaginous capsule of the organ—sometimes replacing the cartilage largely.

It rarely has a plate roofing the organ in part, as in Snakes and Ornithorhynchus. As regards the possession of mucous glands and a peculiar development of vascular tissue, the organ in the Monotremata is essentially mammalian, and bears considerable resemblance to that in the Marsupialia, and somewhat less to that in the Rodentia.

Comparative Table of Relations and Accessories of Jacobson's Organ.

	Anterior Vomer (Palat. Proc. of Premax.)			Septomaxillary.	Turbinal Process.			Organ with	
	Inferior.	Internal.	Superior.		Internal Cartila- ginous.	External Cartila- ginous.	External Cartila- ginous with Vomerine Plate.	Mucous Glands.	Vas- cular Plexus.
Geckonidæ, .	×	×	...	×
Scincidæ .	×	×	...	×	×
Agamidæ, .	×	×	...	×	...	×
Varanidæ, .	×	×	...	×	×
Elapidæ, .	×	×	×	×	×
Ornithorhyn- chus, . .	×	×	×	×	...	×	×
Echidna,	×	...	×	×
Marsupialia,	×	×	×	×
Rodentia, .	×	×	×
Ungulata (Artiodact.),	...	×	×	...
Carnivora,	×	×	...
Chiroptera,	×

I might add, that all the facts in the above table are the result of special original research.

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- (5) PARKER, W. N. "Exhibition of and remarks upon some young specimens of *Echidna aculeata*" at Brit. Assoc. Meeting, Aug. 1891. Also, "On some points in the Structure of the Young of *Echidna aculeata*," *Proc. Zool. Soc.*, 1894.
- (6) WIEDERSHEIM, R. "Die Anatomie der Gymnophionen," Jena, 1879.

EXPLANATION OF PLATE II.

Figs. 1 – 6. Transverse sections of snout of *Echidna* near the anterior end of Jacobson's organ, $\times 10$. *n.s.*, nasal septum; *p.c.*, "palatal" cartilage; *a.n.t.*, alinasal turbinal; *o.a.n.*, outer moiety of alinasal; *p.m.x.*, premaxillary; *a.n.p.c.*, naso-palatine canal, anterior curve at entrance to Jacobson's organ; *a.n.*, alinasal; *r.a.n.*, reflected portion of alinasal; *n.p.c.*, naso-palatine canal; *i.p.c.*, inner moiety of "palatal" cartilage; *o.p.c.*, outer moiety of "palatal" cartilage; *J.o.*, Jacobson's organ.

Fig. 7. Transverse section of snout of Ornithorhynchus in region of naso-palatine canal, $\times 24$. *n.s.*, nasal septum; *d.b.b.*, dumb-bell bone; *g.t.*, glandular tissue at base of nasal valve; *o.p.c.*, outer moiety of "palatal" cartilage welded with the alinasal; *J.o.*, Jacobson's organ; *t.J.o.*, turbinal of Jacobson's organ.

Fig. 8. Transverse section of Jacobson's organ of ripe embryo Gecko, $\times 48$. *n.s.*, nasal septum; *s.mx.*, septo-maxillary; *mx.*, maxillary; *vo.*, vomer; *i.J.o.*, inner part of Jacobson's organ cartilage; *o.J.c.*, outer part of Jacobson's organ cartilage; *J.o.*, Jacobson's organ.

Fig. 9. Anterior part of palate of Ornithorhynchus, showing relative size and position of Jacobson's organ, *J.o.* Nat. size. The shaded portion represents the turbinal.

Fig. 10. Ditto of *Echidna*, $\times 3$.

Fig. 11. Transverse section of Jacobson's organ in *Echidna*, $\times 50$. *n.s.*, nasal septum; *n*, nerves; *a*, arteries; *t.J.o.*, turbinal of Jacobson's organ; *g*, glands; *g.r.*, glandular ridge; *d.g.*, ducts of glands; *v*, large vein; *t.c.*, transitional cartilage; *v.p.*, vessels of turbinal plexus; *p.p.*, palatine plate of cartilage; *c.e.*, ciliated epithelium; *s.l.*, sensory layer; *d.c.t.*, dense connective tissue.

The dotted structures are cartilages; the shaded parts, bones.

ADDENDUM.

APPENDIX.—Since sending off the above paper I have had the opportunity, through the kindness of Prof. Wilson, of consulting Prof. W. N. Parker's paper referred to above, but of which I had only seen his notice in *Nature*. In this paper Prof. Parker has described and beautifully illustrated by sections the condition of the nose in two stages of the young *Echidna*—measuring respectively along the dorsal curve 12.5 cm. and 21.5 cm. In many points there is seen to be a close agreement between the young and adult condition of parts, whilst there are some interesting differences. The most striking peculiarity of the young skull is the great development of the cartilage of the nasal floor—a development closely resembling the condition in *Ornithorhynchus*, not only in its lateral expansion, but also in its passing between the upper and lower parts of the ossifying premaxilla, as Wilson and Martin believe almost certainly exists in the young *Platypus*. In the adult the great development of the premaxilla, as will be seen, not only obliterates the greater part of the nasal-floor cartilage, but completely removes the alinasal cartilage from the connection with the nasal floor as Parker figures in the young. Furthermore, this portion of the nasal-floor cartilage outside the naso-palatine canal is found as a mere rudiment, which might readily escape the eye, instead of the broad plate seen in the young condition. A little behind the naso-palatine canal, where the inner part of this plate has separated, and is passing below Jacobson's organ, there is a close similarity between the adult and young condition. Parker, I find, agrees with my observation of the absence of ciliated epithelium on the concave side of Jacobson's organ. In the section which he figures of the organ in the young *Ornithorhynchus*, he shows a thick layer of epithelium on the concave side, showing that its absence in the adult is either due to accidental detachment, as thought possible by Symington, or to degeneration, as I have suggested. This same section further shows the cartilage of the nasal floor distinct from the alinasal cartilage, as I have assumed probable from comparative reasons.

THE EFFECTS UPON THE TESTES OF LIGATURE OF
THE SPERMATIC ARTERY, SPERMATIC VEINS,
AND OF BOTH ARTERY AND VEINS. By JOSEPH
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and Surgeon to Addenbrooke's Hospital.* (Plate III.).

THE following investigation was undertaken with the view of determining the structural changes that supervene in the testis of an animal (dog) after ligation (1) of the spermatic artery; (2) of the spermatic veins; and (3) of both artery and veins.

In the dog, for instance, the vascular arrangement of the testis is the same as that in man; that is, there is a long and slender spermatic artery which goes to, and supplies in the main, the body of the testis, and also a long artery to the vas deferens which supplies the greater part of the epididymis, and which, at its termination, anastomoses with the spermatic artery, and so contributes to the supply of the body of the testis; and there is a large pampiniform plexus of veins leading out of the body of the testis and up the spermatic cord into the abdomen, as in man.

The animals used were healthy, as far as could be judged, both the vascular arrangement and the testis being normal in each case.

The testis, as is well known, is chiefly made up of seminal tubules, which, with the exception of a thin outer covering of connective tissue (*membrana propria*), are composed of cells; and these cells are, in the adult, actively engaged in reproducing themselves, and in the production of the most specialised and most power-giving cells in the animal world—the spermatozoa. Accordingly, the testis is mainly made up of tubules filled with

actively growing cells, which are chiefly engaged in the production of other and more specialised cells. Such a structure, it may be supposed, would be very liable to alterations, especially in the power of the seminal cells to reproduce one another, and still more in their power to produce more specialised cells—the spermatazoa—whenever any changes occurred in the vascular supply to the organ through interference with the arterial or venous currents.

It may, perhaps, be of interest to give here a short account of the progress of our knowledge regarding the effect of vascular derangements upon the testes before giving the results of any experiments.

HARVEY (1) suggested, and in one instance carried into practice, ligation of the spermatic artery in a case of tumour of the testis, thinking that atrophy of the gland, together with that of any growth it contained, would occur. This operation was followed only by partial success, owing, we now know, to the indomitable power of the cells in new growths. This practice, no doubt rightly, soon fell, if it ever gained any reputation, into disuse.

Harvey's idea that atrophy of the testis would result upon closure of the spermatic artery received a striking confirmation many years afterwards, when WARDROP (2) observed that atrophy of both testes occurred in a man of middle age during the progress of an aneurysm of the abdominal aorta, in which the orifices of the spermatic arteries became blocked. The dwindled state of the testes was referred to interference with the flow of blood along the spermatic arteries, and to the inefficiency of any collateral circulation to adequately supply arterial blood to the glands. I am not aware that a similar case, unilateral or bilateral, has since been observed; and the view that atrophy of the testis results after ligation, or blockage by disease, of the spermatic artery rests solely upon Wardrop's case.

Sir ASTLEY COOPER (3), who was the first to investigate by experiment the effect upon the testis of ligation of the blood-vessels in the spermatic cord, on one occasion ligated the spermatic cord (all its structures included) in two places, and divided it between them. Sloughing and gangrene of the testis followed. Sir Astley seems to have been content with the result of this single experiment. Since this, surgeons, up to within recent years, dreaded tying the spermatic artery with the veins in cases of varicocele, lest sloughing of the testis should occur; and many suggestions have been made from time to time in order to avoid including the artery with the veins in the ligature.

A few years ago, MIFLET (4) gave an account of experiments he had performed upon the testes. His results seem to show that the spermatic artery is to be regarded as an *end*, or terminal artery in the sense used by Cohnheim, and that occlusion of the artery, either by

ligation or by emboli, leads to hæmorrhagic infarct of the testis—the body of the organ only being affected. This state of infarction is, according to this writer, characterised by great swelling and tenderness of the gland. The swelling lasts from a few days to a week, and then gradually subsides, leaving the organ much reduced in size and in a dwindled state. He obtained the same result by ligaturing the spermatic veins. Thus, whether the artery or the veins were ligatured, he obtained the same result, namely, hæmorrhagic infarction of the body of the testis, followed by dwindling and atrophy of the gland. But, it may be observed, although complete interference with either the arterial or the venous supply in healthy dogs seems to induce profound changes in the body of the testis, yet it would seem that in man, in whom varicocele exists, the veins of the pampiniform plexus with the spermatic artery may be removed for a considerable length of their course (3 inches) with impunity; that is, without fear of setting up subsequent inflammation, atrophy, or any other apparent change from the normal. This is the view held by KOCHER (5), ANNANDALE, BENNET (6), TREVES (7), and others. Treves says “that ligation of the artery with the veins gives rise neither to sloughing, intense inflammation, nor atrophy of the testicles.” But it cannot be said that this is invariably the case, for JACOBSON (8) gives an account of the case of a lad in whom severe inflammation and gangrene of the testis followed upon ligation of the spermatic veins only, there being no supuration or septic changes in the wound.

Thus the results of surgical experience do not, apparently, agree with those of the experiments performed by MIFLET (4), and to this Kocher draws attention; and KOCHER (5) goes on to say that the results obtained in animals (dogs) are not applicable to man. If, however, the vascular arrangement of the testis be the same in man as in the dog, as in reality it is, it is difficult to understand why the results obtained in man and those obtained in the dog should differ. It must be remembered, however, that in a case of varicocele in man the circulation in the testes may have been for some time interfered with, though it must be said that as yet we have no evidence that it does so, or if it does, of the manner in which that interference takes place, and no knowledge of how the different vessels comport themselves under the altered conditions. Possibly neighbouring veins may enlarge to relieve the engorgement of those in the pampiniform plexus, and thereby would arise a collateral venous circulation.

The results of my experiments, some of which were performed on full-grown animals and some on puppies, will be given under the following headings:—

1. Ligation of spermatic artery.
2. „ „ veins.
3. „ „ artery and veins.

I. LIGATION OF THE SPERMATIC ARTERY.

In order to expose and tie this artery, it is necessary to reach the spermatic cord as high in the inguinal canal as possible, for I find it is quite useless to attempt to find the artery in the midst of the plexus of spermatic veins, which, as is well known, is large below or near the testis, and gradually diminishes as it proceeds upwards, until, at the internal ring, it is represented only by two, or it may be three, veins. Among these latter the small artery may be seen, and, with care, separated and tied. The artery, in the majority of the following experiments, was secured at this spot, namely, high up in the inguinal canal. In each experiment morphine and chloroform were administered, and anæsthesia throughout maintained; and all antiseptic precautions were used in order to secure an aseptic state of the wound and quick healing.

Experiment I.—A black-and-tan terrier, about 2 years old. On November 13th, 1890, while the animal was under the combined influence of chloroform and morphine, the *right* spermatic artery was tied with a sterilised silk ligature. On the following day (November 14th) the testis was softer and smaller than its fellow, the left. On November 15th, the second day after the ligation, when the animal was killed, the testis was much smaller and softer, and of a bluish appearance, although the veins were not engorged. This testis, *right*, measured 20 mm. in length by 13 mm. in breadth; whereas the left measured 30 mm. in length by 20 mm. in breadth (see fig. 1). Under the microscope the seminal tubules were seen to be greatly reduced in number, and the majority of them much reduced in size, many not exceeding half their natural diameter. In large areas, but not uniformly throughout the gland, the seminal tubules were widely separated from one another by increase, which was in the main relative, of the intertubular connective tissue, caused by infiltration with fibrin and white blood corpuscles (see fig. 2). In these areas the seminal tubules were most markedly changed, the spermatozoa having completely disappeared, and the spermatogenetic cells being either in a state of necrosis or being represented by small closely-packed round cells (see fig. 2). In the remaining portions the seminal tubules, though reduced in size and changed in their internal structure, were not widely separated from one another, and the intertubular connective tissue was not infiltrated with fibrin, but merely increased relatively. In these seminal tubules the spermatozoa were absent, and the greater number of the spermatogenetic cells were also absent, their place being taken by large epithelial cells with much clear protoplasm, which contained many minute granules of fat that stained black with osmic acid. There

were also large multi-nucleated cells, evidently formed by the fusion of the degenerated epithelial cells (see figs. 3 and 4). In the inter-tubular connective tissue the capillaries were large and numerous, but only a few connective-tissue cells, some of which were granular and showed fat-granules. The venous channels of the tunica vasculosa were enlarged.

Experiment II.—A fox-terrier, 3½ years old. On February 15th, 1895, the dog being under the influence of morphine and chloroform, the *left* spermatic artery was ligatured with sterilised silk. On the following day the body of the *left* testis was somewhat smaller and softer than that of the right. On February 20th, 1895, the dog was killed, when the *left* testis was found decidedly, though not markedly, smaller than the right, and it was *soft* and bluish from engorgement of the veins in the tunica vasculosa.

Under the microscope, the seminal tubules were found to be only slightly diminished in size, and there was but little increase in the intertubular connective tissue, and there was an absence of fibrinous infiltration. In the greater number of the tubules the spermatozoa, and, indeed, the spermatogenetic cells, had disappeared, but in a few of the tubules the heads of the spermatozoa, huddled together, could still be distinctly seen. In the old tubules in which the spermatozoa had disappeared, there was the usual single and continuous layer of small cubical cells lining the tunica propria; but within this layer the spermatogenetic cells were replaced by irregular-shaped masses of homogeneous substance, evidently the result of glassy transformation and fusion of the degenerated spermatogenetic cells. Between these masses there were cells, the protoplasm of which was swollen or very granular. The remaining cells were in a state of fatty degeneration, the fat being in the form of very minute granules. In the inter-tubular connective tissue, which in this instance was not much increased, the lymph spaces were distended with spindle-shaped cells loaded with fine fat-granules. Veins in tunica vasculosa much distended.

The *left* testis, which was left undisturbed, was of natural structure, and in the seminal tubules spermatogenesis was going on, and spermatozoa were abundant.

Experiment III.—A fox-terrier, 3 to 4 years old. On January 27th, 1895, the animal being under the influence of morphine and chloroform, the *right* spermatic artery was tied high up in the inguinal canal. On the following day (January 28th) there was no swelling and no tenderness of the corresponding testicle. In the course of the next two days the body of the testis became softer and smaller than natural. On February 9th, 1895, thirteen days after the operation, the dog was killed. The *right* testis was diminished in size, measuring 28 mm. in length by 17 mm. in width, soft and bluish, from turgidity of the veins, whereas the *left*, which was natural, measured 30 mm. in length by 25 mm. in breadth, the usual size of a testis in a fox-terrier. The epididymis was small though natural, and the tunica vaginalis was normal, showing no traces of previous inflammation.

The seminal tubules were much reduced in size and in number, and widely separated by increase, in the main relative, of the inter-

tubular connective tissue, which was not much, if at all, infiltrated with coagulated fibrin, but was mainly composed of spindle-shaped connective-tissue cells, many of which were filled, and it may be said loaded, with fine granules of fat. In the seminal tubules, that were much reduced in size, the epithelial cells were few in number, with a large amount of protoplasm with granules of fat; in others the epithelial cells were represented by small irregularly-shaped cells, which also contained in their protoplasm many fat-granules; and in others there were, in addition to the fatty degenerated epithelial cells, remains of spermatozoa in the middle of the tubules. Thus the epithelial cells of the tubules had undergone fatty degeneration, and, presumably, after dissolution of the protoplasm of the cells, the fat-granules escaped, and were by some means conveyed into the lymph stream of the inter-tubular connective tissue, and thence into the general circulation. Similar changes were taking place in the newly-formed connective-tissue cells in the intertubular stroma.

Experiment IV.—A fox-terrier, about 2 years old. On October 16th, 1890, while the animal was under the influence of morphine and chloroform, the *right* spermatic artery was tied with sterilised silk ligature. On the following day (17th) the testis, *right*, was distinctly smaller and softer than its fellow, the left, which was normal. On the 20th the testis swelled greatly and became tender without any apparent cause; this swelling soon subsided. But on the 23rd the swelling was somewhat greater. After this the organ steadily diminished in size. On November 1st, fifteen days after ligation of the spermatic artery, the dog was killed. The *right* testis was smaller than the left, the former measuring 27 mm. in length by 16 mm. in breadth, and the latter 30 mm. in length by 18 mm. in breadth, and the seminal tubules were very indistinct, as if they had fused with one another. The *right* epididymis, as well as the tunica vaginalis, was quite natural, and showed no signs of inflammation, and there were no evidences that either had participated with the body of the testis when it swelled two days after the operation.

The seminal tubules were of small size, and widely separated by the relatively increased intertubular connective tissue, which was in many parts infiltrated with coagulated fibrin. The epithelial cells of the tubules were small and irregular or polygonal in shape, with round indistinct nuclei and highly granular protoplasm containing many minute globules of fat; these altered cells were very numerous, quite filling the interior of the tubules. Among them were a few large multi-nucleated cells with granular protoplasm, evidently the result of fusion of the degenerated epithelial cells. There was no trace of spermatogenesis in these cells, and there were no spermatozoa in the interior of the tubules. In some tubules, however, spermatozoa, apparently unaltered, were present in the lumina, although the spermatogenetic cells were altered, and in a state of fatty degeneration. Many tubules were so reduced in size as to be hardly recognisable, these being occupied by a few irregularly-shaped epithelial cells. The tunica propria of the tubules was not altered, but it had become fused with the surrounding cellular intertubular connective tissue.

The intertubular connective tissue was much increased, the increase being relative and due to the diminution in number and in size of the seminal tubules, though, to some extent, it may have been due to the formation of new tissue. It was composed of numerous connective-tissue cells, most of which were small and round, and a few elongated and spindle-shaped cells loaded with fat-granules and globules, between which a little fibrous matrix had been formed. Near the periphery of the gland, that is, under the tunica albuginea, the connective tissue was less cellular and more fibrous than elsewhere.

The *right* epididymis was natural, but the tubules were small and contracted, and the secretion in the interior devoid of spermatozoa.

Experiment V.—Fox-terrier, 1½ years. Testicles full grown. On December 24th, 1894, chloroform and morphia being administered, the *right* spermatic artery was tied with a silk ligature high up in the inguinal canal. On the following day the wound was slightly tender, but the testicle was not enlarged. On the third day (December 27th) the testicle was smaller and softer than its fellow (the left) on the opposite side. A fortnight after (January 7th, 1895) the testicle was drawn up into the groin, and was only about half its natural size and soft. On February 6th, 1895, forty-four days after the operation, the dog was killed. The artery was found securely ligatured. The testicle was small, its body measuring 20 mm. in length by 15 mm. in breadth, with the veins in the tunica vasculosa somewhat turgid and prominent. The seminal tubules could not be discerned nor disentangled as in the normal organ. The epididymis was small, but otherwise natural; and there were no traces of previous inflammation in the tunica vaginalis.

Under the microscope the seminal tubules were found reduced in size and number, and widely separated from relative increase of the intertubular connective tissue. In the tubules, which were about half their natural size, the seminal cells were represented by a continuous layer of small cells at the periphery, and by irregularly-shaped cells in the centre (see fig. 5). The central cells, which were large, and which contained one or more nuclei, had a large amount of protoplasm, in which there were numerous fat-granules (fig. 6); this fatty change was less marked in the cells at the periphery. There were no traces of spermatogenetic cells nor of spermatozoa in any of the tubules. In some of the seminal tubules there were no central cells at all, their place being taken by granular protoplasm containing remains of degenerated cells (see fig. 7). The intertubular connective tissue was composed of fibrous connective tissue, in which there were many dilated capillaries, and in which there were, occupying the lymph spaces which were dilated to a very large size, many large spindle-shaped cells loaded with fat-granules (see fig. 5). Thus, in the seminal tubules the central cells were in a state of extreme fatty degeneration, and in the lymph spaces in the intertubular connective tissue there were numerous large cells loaded with fat-granules. No doubt the diminution in size of the seminal tubules was brought about in great measure by a process of fatty degeneration of the central or spermatogenetic cells; and it would seem probable that after the disintegration

of the protoplasm of these cells the fat-granules find their way into the lymph spaces of the adjacent connective tissue, where they are taken up by the wandering and other cells in the lymph, in order, it may be, to be conveyed into the circulation, and there disposed of.

The tubules in the upper end of the epididymis were natural, but small, contracted, and empty.

The left testis, which had been undisturbed, was natural, of full size, and in the seminal tubules the formation of spermatozoa was going on as usual.

Experiment VI.—A fox-terrier, $1\frac{1}{2}$ years old. On October 30th, 1890, the *right* spermatic artery was tied with sterilised silk ligature. On November 1st, 1890, the testicle, *right*, was somewhat swollen and tender. On November 5th it was much in the same state. On November 10th it was reduced in size and was tender. The epididymis was hardly discernible. The organ continued in this state. On January 22nd, 1891, the dog was killed. The *right* testis, the spermatic artery of which was tied eighty-four days previously, was much reduced in size, measuring 22 mm. in length by 15 mm. in breadth; whereas the left testis, which was normal, measured 30 mm. in length by 18 mm. in breadth (see fig. 8). The body of the *right* testis was more globular than natural, soft, and its internal structure was indistinct, the seminal tubules being indistinguishable from the surrounding tissue. The epididymis was correspondingly reduced, but otherwise unaltered. Under the microscope the seminal tubules, which were more widely separated than natural by relative increase of the intertubular connective tissue, were of different sizes, some being very small, and others as large, if not larger, than those in the normal testes. In the tubules that were much reduced the epithelial cells were altered to small, irregularly-shaped cells, with relatively large nuclei, having among them a few large multi-nucleated cells with a large amount of highly granular protoplasm. In none of these cells were there any evidences of spermatogenesis, nor were there any spermatozoa in the interior of these tubules. In the majority of the larger tubules, the epithelial cells were of the same character, but more numerous; among them there were a greater number of the large multi-nucleated cells, and in these, as in the smaller tubules, there were no evidences of spermatogenesis in the cells, and no spermatozoa in the tubules. In none of the tubules was the *tunica propria* altered or thickened. There were, however, a few of the large tubules in which there were evidences of spermatogenesis and of spermatozoa formed in the usual manner in their interior. These latter tubules seemed as if they were tubules that had recovered their power of producing spermatozoa, and it may be that the large tubules above described are in an earlier stage towards complete recovery.

The intercellular connective tissue was increased, and was composed mainly of fibrous tissue, with a few spindle-shaped and small, round, connective-tissue cells scattered through it. There were no fatty degenerated cells either in the tubules or in the intertubular connective tissue.

Thus, in this instance, there were (1) atrophied tubules which had not recovered ; (2) tubules which were probably in process of regaining their natural structure ; and lastly, (3) tubules which were normal, and at the time of death producing spermatozoa.

Before leaving this subject, which deals with the effects of ligature of the spermatic artery upon the structure of the testis, it may be of interest to give the effect of obliteration of both the spermatic and the deferential arteries. I will give, briefly, the result of one such experiment :—

Ligature of Spermatic Artery and of the Artery to the Vas Deferens.

Experiment VII.—A collie dog, 1 year old. Testicles large and fully developed. On February 21st, 1895, when the animal was under the influence of morphine and chloroform, the left spermatic artery and the artery to the left vas deferens were ligated. On the following day there was no obvious swelling or other change in the body of the testis, but it was tense and somewhat tender. Very little change took place until the dog was killed on February 26th, five days after the operation. The left testis was of nearly natural size, tense, and of a dark-bluish colour, from engorgement of the small veins. On section the seminal tubules could not be seen, as the substance of the organ was much infiltrated with blood, which in some parts was undergoing a change of colour. Under the microscope the seminal tubules were seen to be much reduced in size, and widely separated from one another by much infiltrated intertubular connective tissue. In some of the seminal tubules the epithelial cells had fused together to form a glassy, transparent, structureless mass, having near the centre many minute fat-granules. The individual cells in these tubules could not be distinguished, nor could any of their nuclei be made out, either with or without staining reagents. In other tubules, which were the most numerous, the epithelial cells were considerably reduced in number, and contained in their protoplasm numerous minute fat-granules. The spermatozoa had disappeared, and the natural arrangement of spermatogenic cells was absent (see fig. 9). The intertubular connective tissue was in parts much infiltrated with extravasated blood and coagulated fibrin, and with small round cells, which were in the majority of places simply loaded with fat-granules. In some parts there were large connective-tissue cells, filled with fat-granules occupying the dilated lymph channels.

Ligation of Spermatic Artery in Dogs.

No.	Age.	Nature of Operation.	Date.	Animal killed.	Time kept alive.	Results.
I.	2 yrs.	Ligation of Right Sp. Artery.	Nov. 18, 1890.	Nov. 15, 1890.	2 days.	Great diminution in size of body of testis, which was at death soft and bluish. Disappearance of many seminal tubules from rapid degeneration of seminal cells, &c.
II.	3½ yrs.	Ligation of Left Sp. Artery.	Feb. 15, 1895.	Feb. 20, 1895.	5 days.	Diminution in size of body of testis, which was soft and bluish. Destructive changes not nearly so marked as in Exp. I. Seminal cells altered, and spermatogenesis had ceased, with disappearance of spermatozoa from majority of tubules.
III.	3 to 4 years.	Ligation of Right Sp. Artery.	Jan. 27, 1895.	Feb. 9, 1895.	13 days.	Diminution in size of body of testis, which was, as in Exps. I. and II., soft and bluish. Seminal tubules reduced in size and number, no spermatozoa, and seminal cells in a marked state of fatty degeneration.
IV.	2 yrs.	Ligation of Right Sp. Artery.	Oct. 16, 1890.	Nov. 1, 1890.	15 days.	Diminution in size of body of testis. Reduction in size and number of seminal tubules. No spermatozoa. Relative increase of intertubular connective tissue, which was infiltrated with coagulated fibrin. Fatty change in epithelial cells in tubules and fatty cells in lymph spaces.
V.	1½ yrs.	Ligation of Right Sp. Artery.	Dec. 24, 1894.	Feb. 6, 1895.	44 days.	Diminution in size of body of testis; small and soft. Reduction in size and number of seminal tubules. Disappearance of majority of spermatogenetic cells, with fatty degeneration of remainder; relative increase of intertubular connective tissue.
VI.	1½ yrs.	Ligation of Right Sp. Artery.	Oct. 30, 1890.	Jan. 22, 1891.	84 days.	Body of testis remained small. Seminal tubules partially recovered, spermatogenetic cells being more numerous, and in a few tubules spermatozoa were being formed, and there were some free in the interior.

Ligation of Spermatic Artery and the Artery to the Vas Deferens.

VII.	1 year.	Ligation of L. Sp. A., and A. to the L. Vas Deferens.	Feb. 21, 1895.	Feb. 26, 1895.	5 days.	Body of testis of natural size, tense and engorged with venous blood. Great destruction of seminal tubules, and infiltration with coagulated fibrin of intertubular connective tissue.
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Resumé.

When the spermatic artery is tied in the groin there occurs, as a rule, diminution in the size of the body of the testis. Two or three days after ligation of this artery the body of the testis is obviously diminished in size, and it is found softer and of a bluish colour, presumably from sluggishness of its venous circulation, due to the loss of the *vis a tergo* from occlusion of the artery. The testis becomes small, and remains, at least for three months, as in Exp. VI., in a more or less similar state, namely, soft and of a bluish colour. The epididymis becomes somewhat, though not proportionately, diminished from contraction of its tubules, due to want of seminal secretion to distend them. No inflammation of the tunica vaginalis is produced.

During the first few days after ligation of the spermatic artery, the epithelial cells in the majority of the seminal tubules, together with the spermatozoa and the spermatic secretion, rapidly disappear, from what might be called dissolution of the protoplasm of the cells. I have been unable to trace the various steps in this process, and am unable to conjecture what really happens.

While the seminal tubules are undergoing this progressive diminution in size, the intertubular connective tissue becomes relatively, but not actually, increased; and here and there considerable effusion of fibrin, which soon coagulates and forms a meshwork, takes place. Into this infiltrated intertubular connective tissue leucocyte-like cells make their way, and soon replace the coagulated fibrin. In portions of the testis no disturbances take place in the intertubular connective tissue, and in these parts, perhaps, the most striking feature, in addition to the destructive changes in the seminal tubules, is dilatation of the capillaries, which are often devoid of blood corpuscles, but which are filled with coagulated structureless material. Accordingly, the diminution in size of the testis, after ligation of the spermatic artery, is due to a progressive diminution in the size of the seminal tubules, owing to the dissolution and subsequent disappearance of the spermatozoa and of the spermatogenetic cells, the nature of this process of dissolution being obscure; and during this process of dissolution of the epithelial cells of the seminal

tubules there is a liability, here and there, to the effusion of fibrin into the intertubular connective tissue, which soon coagulates, and later on becomes replaced by leucocyte-like cells.

After some weeks the epithelial cells of the tubules may be found, as in Exp. V., in which the testis was examined forty-four days after ligation of the spermatic artery, to be in a state of extreme fatty degeneration, and the lymph spaces in the intertubular connective tissue occupied by large spindle-shaped cells loaded with fat-granules. It would appear that the epithelial cells become after a time fatty and then disintegrate, it may be by a process of self-digestion, the fat-granules being set free and taken up by the lymph stream, where they are at once devoured or incepted by the wandering and amœboid lymph corpuscles, which act as carriers to the general circulation.

During this progressive diminution in size of the seminal tubules they lose their spermatozoa-producing powers, which, as in the only instance in which I kept the dog alive long enough (three months), may be regained; but they do not lose that influence which the testicle exerts on the body generally, and upon the maintenance of full size in the accessory sexual glands,—for example, the prostate. In case of castration, the prostate gland shows (within a short time) signs of atrophy of the glandular tubules. But in case of ligation of the spermatic artery, followed by this partial dwindling of the testis, no such atrophic changes arise in the glandular tubules.¹

In one dog, in which the spermatic artery had been ligatured for three months, and in which the testis was, soon after the application of the ligature, reduced to a small size, a few of the seminal tubules, though they had not regained their natural and full size, yet contained spermatogenetic cells, which were, at the time of the death of the animal, actively engaged in the production of spermatozoa, many of which could be seen occupying

¹ Therefore ligation of the spermatic artery would not be sufficient as a substitute for castration. Indeed, this has been tried in the horse (see Williams' *Veterinary Medicine*), and, through want of success, the method has been abandoned. In the human subject, ligation of the spermatic artery has been suggested as a substitute for castration in men suffering from enlargement of the prostate gland; but as the testis only partially dwindles, and as its power of producing spermatozoa may be regained, it is highly improbable that the prostate may in any way be influenced.

the lumina of such tubules. In this instance, therefore, it is probable that the seminal cells regained their power of producing spermatozoa, and thus the full function of the testis would be re-established.

It would seem that after a time collateral circulation through the artery to the vas deferens can be set up, and that this is sufficient to prevent complete destruction or dissolution of the seminal cells in the seminal tubules, and in time to restart the process necessary for the production of spermatozoa. Thus we may say that ligation of the spermatic artery in dogs produces great diminution in the size of the seminal tubules, which lose for a time the power of producing spermatozoa, but which, after a time, regain that power; and although the testis may not reacquire its full size, yet it may become capable of again producing the spermatic secretion. When, however, the artery to the vas deferens as well as the spermatic artery is ligated, then there follows in some parts necrosis of the epithelial cells in the seminal tubules, and in others great destruction and ultimate disappearance, through a process of fatty degeneration of the seminal cells,—such a destruction as, probably, would not be followed by recovery, as is the case after ligation of the spermatic artery alone.

The results of the above experiments differ widely from those obtained by Miflet (1) by tying the spermatic artery, or (2) by embolism of the same. He considers the spermatic artery to be like one of the terminal arteries of the spleen, the blocking of one of which produces a typical hæmorrhagic infarction. In hæmorrhagic infarction the body of the testis would become greatly swollen from extravasation of blood, and would subsequently dwindle to a small mass of fibrous connective tissue, in which there would be only traces of the seminal tubules and cells. This condition can be readily induced, as I shall show immediately, in full-grown dogs by ligation of the spermatic veins, and in puppies by ligation of both spermatic artery and veins, but not, so far as I have been able to ascertain, by ligation of the spermatic artery alone. I am, therefore, unable to agree with Miflet in regarding the spermatic artery as an end artery, nor do I find that ligation of it induces anything like hæmorrhagic infarction of the testis.

It may be of interest to observe at this point how large and how numerous are the lymph spaces in the intertubular connective tissue of the body of the testis, as it is, I think, upon this free lymph circulation that such great absorption (as was seen in Exps. I., V., and VI.) of the tubular structure of the organ depends. When the spermatic artery is tied the testis may during the first forty-eight hours diminish to about one-half its natural bulk. It would appear that the absorption takes place through these lymph spaces, and that it is consequent upon the dissolution of the epithelial cells, there being, probably, a lymph current from the interior of the tubules to the lymph spaces at the periphery in the intertubular connective tissue. This view is strongly supported by the conditions to be seen in the testis a few weeks after ligation of the spermatic artery. In Exp. V., for example, the epithelial cells in the seminal tubules were in an extreme degree of fatty degeneration, and in the lymph spaces there were numerous fat-granules, some being quite free, but most of them in large connective-tissue cells, probably *carrying* or *wandering* cells. In this instance it is reasonable to suppose that the epithelial cells in a certain stage of fatty degeneration undergo complete dissolution, the fat-granules being set free and conveyed by the lymph stream into the lymph spaces around the tubules, where they would be eagerly devoured by the *wandering* or *carrying* cells, always present there. These *wandering* cells, loaded with fat-granules, would then become conveyed into the systemic lymph channels, and ultimately into the circulation, where both cell and contained fat would be disposed of. This process of absorption seems to be similar to that which I have described as one of the chief processes taking place during the disappearance of the tadpole's tail, while metamorphosis from tadpole to frog is taking place (see *Journ. of Bact. and Path.*, vol. iii. p. 131).

I hope on a future occasion to give the results of instances in which a larger interval has intervened between the ligation of the spermatic artery and the death of the animal, and more particularly with reference to the recovery of the spermatogenic power : also of other examples, in which the deferential artery as well as the spermatic has been tied.

II. LIGATION OF THE SPERMATIC VEINS.

Just as in the case of the spermatic artery, the veins can only be successfully ligated separately if exposed well up in the inguinal canal, where they are only two to three in number, and where they can, with comparative ease, be separated from the spermatic artery, which runs in intimate relation to them. As the result of the following experiment, which is the only one of its kind I performed, agreed with the results of previous workers (Miflet, among others), it seemed hardly worth while to perform others.

**Experiment VIII.*—A large sheep-dog, from 3 to 4 years old. On June 20th, 1890, while the animal was under the influence of morphine and chloroform, the right spermatic veins were tied with sterilised silk ligature. On the following day the right testis was much swollen, tense and tender, the skin of the scrotum being dusky and oedematous, with largish veins visible in it. After the third day this swelling began to subside, which it did rapidly. On July 1st, 1890, eleven days after the operation, the animal was killed.

The *right* testis was large, and measured 30 mm. in length by 28 mm. in breadth, the *left* being 30 mm. in length by 24 mm. in breadth. It (*right*) was almost globular in shape, of a bluish appearance, and firm in consistency. The *tunica vaginalis* was normal. On section of the gland the seminal tubules could not be distinguished, the structure being more or less uniform, and in it there were small irregular patches of discoloured blood, as if the result of hæmorrhages. Under the microscope the seminal tubules were widely separated from one another by intertubular connective tissue, which was much infiltrated with coagulated fibrin and white and red blood corpuscles. In the seminal tubules, none of which presented the normal structure, the spermatogenetic cells were replaced by small round cells of different sizes (see fig. 10). The protoplasm of these small cells was somewhat glassy, though not transparent, and it reacted indifferently to staining reagents, just as the protoplasm of cells that are undergoing the process of necrosis; the nuclei were obscured, and also did not stain. In many of the tubules, some of these altered cells had fused together to form an irregularly-shaped mass of non-nucleated and structureless protoplasm; but in a few of these some remains of spermatozoa were still to be detected among the altered cells occupying the centres of the tubules. There were in some of the tubules extravasated red blood corpuscles, due to minute hæmorrhages. The *tunicæ propriæ* of the tubules were not thickened, but they were merged with, and indistinguishable from, the surrounding connective tissue. The

* This and other experiments prefixed with an asterisk were performed, through the kindness of Prof. Dastre, in his laboratory in the Sorbonne, Paris.

intertubular connective tissue was much infiltrated with fibrin, which had coagulated and filled the interstices of the normal connective tissue. In the infiltrated parts were numerous red blood corpuscles and a few white, the former already showing signs of disintegration and breaking up into small globules. The blood-vessels were large and distended; many of them were filled with blood and coagulated fibrin. The veins in the *tunica albuginea* were universally large and prominent, and it may be that to the presence of these distended veins the bluish appearance of the organ was due.

Ligation of the Spermatic Veins in Dogs.

No.	Age.	Operation.	Date.	Animal killed.	Time kept alive.	Result.
VIII.	3 to 4 years.	Right Sp. Veins tied with silk.	June 20, 1890.	July 1, 1890.	11 days.	Great swelling, congestive cyanosis of testes and scrotum. Destructive changes in seminal tubules.

Resumé.

Ligation of the spermatic veins in a full-grown dog leads to great swelling and congestion of the body of the testis, which is accompanied by cedema and enlargement of veins in the scrotum. This is truly a *hæmorrhagic infarction* of the testes, and in it the epithelial cells of the tubules undergo necrosis, in which they are transformed into a glassy homogeneous substance, and the intertubular connective tissue becomes greatly infiltrated with coagulated fibrin and extravasated blood, the latter having also found its way into the interior of many of the altered seminal tubules. This is, in all probability, followed by transformation of the organ, more or less completely, into dense fibrous connective tissue, in which remains of the once tubular structure of the gland may be seen in the solid rods of fibrous tissue traversing its substance.

III. LIGATION OF SPERMATIC ARTERY AND VEINS.

(a) *In Puppies.*

Experiment IX.—A young fox-terrier, about 6 months old. The testes were of small size and undeveloped. On December 6th, 1891,

the *left* spermatic artery and veins were tied with sterilised silk ligature. On the following day (7th) the *left* testis was much swollen, nearly twice as large as its fellow, the right, which was left undisturbed. The swollen state of the testis remained until the 10th, four days after the ligaturing of the vessels, when the animal was killed. The *left* testis was nearly twice as large as the right; it was congested, and of a bluish colour. On section, the seminal tubules could not be discerned, as they were embedded in a more or less uniform mass of soft reddish tissue, in which blood had been extravasated. The epididymis was normal, and so was the *tunica vaginalis*. Under the microscope the seminal tubules were much reduced in size and in number, and widely separated by an infiltrated intertubular tissue. Many of the tubules were filled with a confused mass of epithelial cells, evidently in process of necrosis; others were occupied by small round cells. The intertubular connective tissue was much increased, being infiltrated with coagulated fibrin, and in places with extravasated blood. In many of the lymph spaces in the connective tissue there were large connective-tissue cells, with a large amount of protoplasm filled with fat-granules and fat-globules which obscured the nuclei. The *tunica albuginea* was thickened, and in it the vessels were unusually dilated. There were no changes in the epididymis. The opposite (right) testis, the vessels of which were left undisturbed, presented the natural structure of a testis at the age of 6 months.

Experiment X.—A fox-terrier, from 5 to 6 months old. On August 10th, 1891, while the animal was under the influence of morphine and chloroform, the *right* spermatic artery and veins were tied. On August 11th the right testis was swollen, tense, and tender. After three or four days the swelling began to diminish, and continued doing so until the organ was reduced to a very small size on September 13th, 1891, when the animal was killed, thirty-three days after ligation of both artery and veins. The microscopic as well as naked-eye appearances of this testis were the same as those described in detail in the following experiment, and therefore they need not be given here.

Experiment XI.—A black-and-tan terrier, from 3 to 4 months old. The testicles were small and undeveloped. On July 21st, 1891, while the animal was under the influence of morphine and chloroform, the (*right*) spermatic artery and veins were tied. On July 23rd the (*right*) testis was enlarged and tender. In this state it continued for some days, and then gradually diminished until the beginning of October (3rd), when it was felt as a small, hard knot. On November 28th, 1891, 18½ weeks after the operation, the animal was killed. The testis, as depicted in fig. 11, was very small, but the epididymis was relatively large, and appeared as if it had not shared at all in the diminution. The body of the testis was firm in its structure, and on section the seminal tubules could not be seen. The *tunica vaginalis* was natural. Under the microscope, the testis showed that the seminal tubules had, in the centre of the gland, almost entirely disappeared, though near the periphery, that is, under the *tunica*

albuginea, a few altered tubules were still seen. Where the tubules had entirely disappeared, the organ was composed of dense, fibrous connective tissue, traversing which were numerous cords or rods of fibrous tissue disposed differently to that of the remainder of the gland; these rods of fibrous tissue being the only representatives of the seminal tubules.

Of the few remaining seminal tubules none were normal. The largest, which had a tunica propria of natural thickness, were lined by a single layer of tapering cells attached to the wall of the tubules at their base, and projecting into and occupying the lumen.

There were no spermatogenetic cells, nor were there any traces of spermatozoa. The smallest tubules were represented by a thin tunica propria, having within a thick layer of almost transparent connective tissue, and their lumina were occupied by a few polygonal-shaped cells huddled together (see fig. 12).

In the epididymis the tubules were small and empty, and the columnar cells lining them were without cilia; the intertubular connective tissue was large in amount, and fibrous.

Ligation of Spermatic Artery and Veins in Puppy Dogs.

No.	Age.	Operation.	Date.	Animal killed.	Time kept alive.	Result.
IX.	6 mos.	Left Sp. A. and Veins tied with silk.	Dec. 6, 1891.	Dec. 10th.	4 days.	Great swelling of testis, with extravasation of blood into connective tissue, and great destruction of seminal tubules.
X.	5 to 6 mos.	Right Sp. A. and Veins tied.	Aug. 10, 1891.	Sept. 13, 1891.	33 days.	Similar to those of No. 11.
XI.	3 to 4 mos.	Right Sp. A. and Veins tied.	July 21, 1891.	Nov. 28, 1891.	128 days	Great swelling of testis followed great atrophy, with almost complete destruction of the undeveloped seminal tubules.

Resumé.

Ligation of the spermatic artery and veins in puppies followed by great swelling, from congestion and extravasation of blood in the body of the testis, which gradually subsides, and the body of the testis decreases until it becomes very small. The epididymis remains more or less normal; and when the body of the testis has reached its ultimate connective size, the epididymis is large, and much out of proportion to it. The body of the testis becomes converted into a small, firm, almost fibrous lump, which retains its original shape; but the epididy-

mis is large, and during the period of growth this testis does not keep pace with its fellow of the opposite side, in which the parts are normal.

Accordingly, in puppies, ligation of the spermatic artery and veins is followed by more or less complete destruction of the seminal tubules in the body of the testis, and after a time the testis is reduced to a small size, and is incapable of growth, as well as of production of spermatozoa.

This condition of the testis, produced experimentally in dogs with comparative ease and with certainty, resembles two morbid states which are known to occur in the human subject.

In the first place, the testis of a puppy, the spermatic artery and spermatic veins of which have been tied some weeks previously, are almost identical in structure with the testes found in eunuchoid persons.¹ And, in the second place, the process in the testes is similar, if not identical, with that which takes place in a testis of a boy or a young man undergoing what is known as spontaneous atrophy, and also with that which takes place in cases of twisting of the spermatic cord, where the testis is undescended and in the groin, or where fully descended and in the scrotum. In all these the testis suddenly swells, undergoes extreme congestion, and ultimately dwindles to a small, diminutive size, from the destruction of the seminal tubules and their replacement by fibrous connective tissue. Although the ultimate result is much the same in each instance, I would not go so far as to say that the vascular lesion is the same in each; yet in case of spontaneous atrophy of one testis, the sudden onset of the pain and swelling justifies the inference that it is due to some sudden derangement in the vascular supply; and in the case of "twisting of the spermatic cord," the changes in the testis are undoubtedly to be ascribed to interference with both venous and arterial supply.

(b) *In Full-grown Dogs.*

Experiment XII.—A spaniel, 12 years old. On August 13th, 1895, while the animal was under the influence of morphine and chloroform, the right spermatic artery and veins were ligated in two places, and the

¹ See paper by me entitled "Testes and Prostate Gland in Eunuchoid Persons," in *Jour. of Anat. and Phys.*, vol. xxviii.

vessels divided between. On August 14th there was some swelling and tenderness of the testis. On August 15th the swelling was somewhat increased. On August 16th, 1895, the dog was killed. The left testis was enlarged, tense, and cyanotic; the spermatic veins up to the seat of ligature were distended, and both the artery to the vas deferens and the veins accompanying the spermatic duct were much distended. The interior of the testis was infiltrated with blood, and the seminal tubules could not be distinguished one from another.

Under the microscope the seminal tubules were widely separated from one another by intertubular connective tissue infiltrated with extravasated blood and coagulated fibrin; and the seminal tubules, though some few showed complete necrosis of the epithelial cells, had blood extravasated into their interior; the spermatozoa had entirely disappeared; and the spermatogenetic cells were replaced by closely packed small round cells. This condition is precisely the same as that seen after ligation of the spermatic veins alone, and after ligation of the spermatic artery and veins in puppies,—in fact, a state of hæmorrhagic infarction.

**Experiment XIII.*—A small, rough-haired terrier, about 4 years old. On the 30th of May 1890, while the animal was under the influence of morphine and chloroform, the *right* spermatic artery and veins were tied. On June 1st the *right* testis was much enlarged, tense, and tender. Some suppuration occurred two days later (June 3rd, 1890) in the wound, and signs of sloughing of the testis appeared. As soon as this was detected, the animal was killed.

Experiment XIV.—A collie dog, 16 months old. Testicles fully grown. On January 20th, 1895, while the animal was under the influence of chloroform, the *right* spermatic artery and veins were tied with silk. No swelling or tenderness followed, and on January 25th, 1895, five days after ligation, the dog was killed. The body of the testis was of normal size, but on section the seminal tubules were pale and yellowish. Under the microscope, it was found that the pale yellow appearance of the seminal tubules was due to fatty degeneration of the spermatogenetic cells, the spermatozoa having in the majority, but not in all, disappeared. The seminal tubules were held more firmly together, and the intertubular connective tissue was slightly increased. Otherwise the testis was of normal structure.

Experiment XV.—A fox-terrier, 1½ years. On April 30th, 1895, while the animal was under the influence of morphine and chloroform, the *left* spermatic artery and veins were ligated with silk. No swelling of testis occurred, and the animal soon got well. The organ soon dwindled, until, six weeks after, it could not be detected in the scrotum on that side. On July 20th, 1895, eighty-one days after the ligation, the dog was killed. There was no trace of either the body of the testis or of the epididymis to be found, but the dwindled spermatic artery, and one or two small veins, could be traced downwards to the small mass of fibrous connective tissue that represented the testis.

Experiment XVI.—A fox-terrier, 16 months old. On March 30th, 1895, while the animal was under the influence of chloroform, the *right* spermatic artery and veins were ligated with silk. No swelling

or tenderness occurred in the testicle. On August 7th, 1895, 130 days after ligation, the dog was killed. The testicle was of natural size, and the seminal tubules appeared normal. Under the microscope, the seminal tubules were found of quite normal structure, and in them the production of spermatozoa was going on as in a perfectly natural testis. The ligature could not be found, and free communications had become established, as injections passed readily along the spermatic artery into the testis.

Is it to be assumed that in this case fatty degeneration of the epithelial cells in the seminal tubules took place, and that they recovered and renewed their spermatozoa-producing powers?

Ligation of Spermatic Artery and Veins in Full-grown Dogs.

No.	Age.	Operation.	Date.	Animal killed.	Time kept alive.	Result.
XII.	10 yrs.	Right Sp. A. and Veins tied.	Aug. 13, 1895.	Aug. 16, 1895.	3 days.	Testis became swollen, tense, and cyanotic. Extravasation of blood into its interior, and destruction of seminal tubules.
XIII.	4 yrs.	Right Sp. A. and Veins tied.	May 30, 1890.	June 3, 1890.	4 days.	Suppuration in wound and sloughing of testis.
XIV.	15 mos.	Right Sp. A. and Veins tied.	Jany. 20, 1895.	Jany. 25, 1895.	5 days.	Extensive and extreme fatty degeneration of spermatogenic cells in seminal tubules.
XV.	1½ yrs.	Left Sp. A. and Veins tied.	April 30, 1895.	July 20, 1895.	81 days.	Complete disappearance of testis without suppuration.
XVI.	16 mos.	Right Sp. A. and Veins.	March 30, 1895.	Aug. 7, 1895.	130 days.	No change in testis. Production of spermatozoa going on as usual.

Resumé.

The results of the preceding experiments (XII. to XVI.) show that ligation of the spermatic artery and veins may lead (1) to sloughing of the testis; (2) to complete disappearance of the testis from wasting; and lastly, (3) to temporary fatty degeneration of the epithelial cells in the seminal tubules, from which they may soon recover and resume their spermatozoa-producing function. We may obtain, as in Exp. XIII., sloughing of the testis, which resulted about the fourth day. This may be due, as under similar conditions in man, to suppuration extending from the wound into the structures of the cord, and thus completely

interfering with the formation of new channels to convey the blood to and from the testis, and also causing blockage of the artery and vein of the vas deferens. Although this was not an uncommon result of attempts at the cure of varicocele in the pre-antiseptic days, it now but rarely occurs, and it is said not to occur in the human subject without septic infection in the wound, which can now almost with certainty be avoided. Complete atrophy of the testis no doubt follows upon changes such as have been described in Exp. XII. three days after ligation of the spermatic artery and veins, in which there was extravasation of blood in the intertubular connective tissue and destruction by necrosis of the epithelial cells in the seminal tubules. The results obtained in Exps. XIV. and XVI. are of interest, as they correspond with the results usually obtained in man after the cure of varicocele according to the plan adopted by Mr Bennett of St George's Hospital.

In Exp. XIV., in which the testis was examined five days after the application of a ligature around the spermatic artery and veins, the only obvious changes from the normal that could be detected in the testis was fatty degeneration of the spermatogenic cells, resulting in a temporary cessation of the production of spermatozoa. In Exp. XVI., in which the testis was examined 130 days after ligation of the spermatic artery and veins, the seminal tubules were found to be normal, and in them the normal process of spermatogenesis was going on when the dog was killed. The results of these two experiments would seem to confirm the view put forward by Mr Bennett regarding the effect of ligation of the spermatic artery with the veins in cases of varicocele in man. He says "that, in cases of varicocele, the division of the main trunk of the spermatic artery, together with the veins, if the ordinary principles of surgical cleanliness be observed, is not only harmless to the testicle, but aids in the ultimate relief of the affection [varicocele] by diminishing the pressure of blood going to the testis at the time when almost all the returning veins are suddenly obliterated."¹

Although complete atrophy of the testis may occur after ligation of the spermatic artery and veins in full-grown dogs, yet this result does not necessarily follow in the Dog; and in Man, in

¹ Bennett, *On Varicocele*, p. 97.

whom asepsis may be ensured, sloughing is scarcely to be expected. This, therefore—namely, ligation of the spermatic artery and veins—can hardly be of service as a substitute for castration in case of senile prostate disease in man. Prof. White of Philadelphia arrives at a similar conclusion.¹

GENERAL CONCLUSIONS.

1. Ligation of the spermatic artery in full-grown dogs leads, within a few days, to great diminution in the bulk of the testis, caused by rapid destruction from degenerative changes in the seminal tubules; but after a time the remaining tubules may recover to such a degree as to be again capable of producing spermatozoa in the usual way.

2. Ligation of all the spermatic veins leads to great swelling, from engorgement of the veins and extravasation of blood into the intertubular connective tissue, and to necrosis of the epithelial cells in the seminal tubules. This condition would ultimately cause almost complete disappearance of the seminal tubules and atrophy of the gland.

3. Ligation of the spermatic artery and veins in *puppies* leads to great swelling of the testis, followed by a gradual diminution and atrophy of the seminal tubules, and to atrophy of the organ altogether.

4. Ligation of the spermatic artery and veins in *full-grown dogs* may lead, according to conditions not yet known, to (1) sloughing of the testis, (2) complete atrophy, and (3) temporary fatty degeneration of spermatogenetic cells in the seminal tubules, which may be followed by complete recovery.

LIST OF REFERENCES.

(1) HARVEY, *Anat. Exercitations concerning the Generation of Living Creatures*.

(2) WARDROP, Note to his edition of Baillie's Works, vol. ii. p. 315.

¹ See *Annals of Surgery*, July, pl. 31, 1895.

- (3) Sir ASTLEY COOPER, *Diseases of the Testes*.
- (4) MIFLET, "Ueber die pathol. Veränderung d. Hodens durch Störungen der localen Blutcirculation," *Langenb. Arch.*, Bd. 24, s. 399.
- (5) KOCHER, "Die Männlicher. Geschlechtsorgane," *Deut. Chir.*
- (6) BENNETT, *On Varicocele*.
- (7) TREEVES, *Manual of Oper. Surgery*, 1891.
- (8) JACOBSON, *Diseases of the Organs of Generation*.

EXPLANATION OF PLATE III.

Fig. 1. Testes, right and left, drawn to natural size. Right (*a*) much reduced and somewhat globular; left (*b*) natural.

Fig. 2. $\times 50$. Section of right testis, Exp. I., showing diminution in size of the seminal tubules (*a*), and relative increase of the inter-tubular connective tissue (*b*).

Fig. 3. $\times 150$. Seminal tubule from right testis, Exp. I., showing absence of spermatozoa, altered spermatogenetic cells, and many small homogeneous bodies (*a*) between the altered cells.

Fig. 4. $\times 150$. Seminal tubule from same testis as fig. 3, showing fusion of the epithelial cells towards the centre to form multi-nucleated masses (*a*).

Fig. 5. $\times 50$. Section of right testis, Exp. V., showing small size of seminal tubules (*a*), and relative increase of intertubular connective tissue (*b*), the lymph spaces in the latter being crowded with cells loaded with fine fat-granules stained black with osmic acid.

Fig. 6. $\times 350$. Seminal tubules from right testis, Exp. V., showing extreme fatty degeneration of the remaining seminal cells (*a*), the fat-granules being stained black with osmic acid.

Fig. 7. $\times 600$. Seminal tubule from right testis, Exp. V., showing complete disappearance of the spermatogenetic cells, and of the spermatozoa; (*a*) thickened membrana propria; (*b*) single layer of cells at periphery; (*c*) granular protoplasm containing remains of a few degenerated cells in the centre.

Fig. 8. Natural size. Testes from dog, Exp. VI. Right (*a*) much reduced, the spermatic artery having been ligated 84 days before death; left (*b*) natural.

Fig. 9. $\times 130$. Section of right testis, Exp. VII: (*a*) seminal tubules in which the epithelial cells are fused together and necrosed; (*b*) tubules in which the epithelial cells have almost entirely disappeared, leaving only irregular, very granular masses of protoplasm with indistinct nuclei in their places. Spermatozoa absent. Intertubular connective tissue (*c*) relatively increased, and fibro-cellular in character.

Fig. 10. $\times 50$. Section of right testis, Exp. VIII. Seminal tubules (*a*) filled with small round cells; (*b*) intertubular connective tissue infiltrated with coagulated fibrin and red and white blood corpuscles.

Fig. 11. Natural size. Testes from dog, Exp. XI. Right testis much atrophied 128 days after ligation of both artery and veins; epididymis (*a*) relatively large; (*b*) body of testis. Left natural.

Fig. 12. $\times 350$. Section of right testis, Exp. XI.: (*a*) tubules converted into rods of fibrous connective tissue; (*b*) tubules still containing representative of the epithelial (seminal) cells; (*c*) thickened intertubular connective tissue.

A CRITICAL NOTE ON COLOUR VISION. By
JOHN TENNANT.

THE appearance of a book by Captain Abney,¹ containing some criticisms of current theories of vision, is the occasion of this note.

This book is the result of so much admirable experimental skill, is so interesting a record of manifold observations, is so lucidly expressed, and is written in so judicial a spirit, as to cause the writer of this note to regret that, in part owing to the fact that some recent developments have apparently escaped Captain Abney's notice, a book which will be so widely read by English students should contain a critical estimate of Hering's theory of vision which still leaves much to be desired.

It would appear, indeed, that the important paper by Hillebrand, read in 1889 before the Vienna Academy, had entirely escaped the notice of English authors. The diagram in Abney's book representing the curves of sensation in the spectrum on Hering's hypothesis is taken from Prof. Michael Foster's *Physiology*,² published in 1891, and was produced unchanged by the committee of the Royal Society in their recent report³ on colour vision, but it contains a vital misrepresentation of Hering's theory. That diagram places the maximum sensation of white in the yellow of the spectrum, but in 1887 Hering showed, in a critical note on a paper of Holmgren's,⁴ that he was already aware that the maximum of the white sensation was produced by the spectrum green; and Hillebrand's paper,⁵ which

¹ "Colour Vision, being the Tyndall Lectures delivered in 1894 at the Royal Institution by Capt. W. de W. Abney, D.C.L., F.R.S."

² Foster, *Text-Book of Physiology*, 5th ed., p. 1233.

³ *Report of Royal Society Committee on Colour Vision* (Apr. 1892), p. 289.

⁴ *Pflüger Archiv f. Physiologie*, Bd. xl. p. 19.

⁵ Hillebrand, "Ueber die spezifische Helligkeit der Farben," *Sitzungsber. d. Kais. Akad. d. Wissensch. zu Wien*, math. nat. Classe, Bd. xcvi. p. 70 (1890).

has a preface by Hering himself, contains a thorough discussion of the whole question. Hillebrand uses in his investigation the same method of extinction which Captain Abney explains in his book; and the latter's work, so far as it goes, completely confirms his results. Since the publication of this paper, which affects the critical estimate of Hering's theory at every point, Hering's curve for white has been identical with Abney's "persistency curve."

In his original work, Hering seems to have considered, with some hesitation, that whiteness and luminosity were completely identifiable,¹ and that the colours had nothing in common with white, although capable of being treated in practice as of the brightness of the neutral grey. This is, however, by no means the only or the most natural supposition. Just as loudness is a property of sounds of different tone, so brightness, as indeed the Young-Helmholtz theory assumes, may be a common property of visual sensations of distinct quality. But the antagonistic nature of the colour effects in the elementary substances, on Hering's hypothesis, seems to require that if we assume an effect of brightness for all dissimilative changes, then we must assume a darkening effect for all assimilative changes; and, without actual proof, this may well have appeared to Hering too unexpected a supposition to be easily entertained.

The position is now altered. Hering's discovery of the true position of the curve for white has made his original supposition untenable, and Hillebrand has proved that the second hypothesis is in complete accordance with the facts. He has shown that if two blues of the same hue appear by the method of extinction to possess the same white valence, then the more saturated colour, *i.e.*, the one with the greatest relative blue valence, is the darker of the two, and that this difference increases with increase of illumination.² The reverse is the case with two yellows, the more saturated being the brighter, and an analogous law holds for green and red.

Hillebrand's experiments were all made with colours of moderate luminosity, and his demonstration applies strictly only to such cases.³ Moreover, he has found no means to compare

¹ Zur Lehre vom Lichtsinne v. E. Hering, sec. 40, p. 123, and sec. 41.

² *L.c.*, p. 100.

³ *Do.*, p. 105.

the saturation of colours of different hue, for this requires more than a comparison of their white valences,—it requires a comparison of the degree in which their coloured parts contribute respectively to the total visual result,¹ but, in his opinion, the order of the elementary sensations in specific brightness is white, yellow, red, green, blue, and black.

It is not observed by Hillebrand, but seems a logical consequence of the laws of colour mixture hereafter mentioned, that if we regard equal quantities of blue and yellow as those which neutralise one another, and if we suppose that the brightness of the colour formed by their union is that of the neutral grey, then the specific brightness of the pure blue sensation is as much darker than the neutral grey (*i.e.*, the grey of the field of vision in the absolutely rested eye) as the specific brightness of the pure yellow is brighter, and a similar reciprocal relation must hold for green and red. The warm colours of the artist are, in a literal sense, colours of the light, and the cold colours, colours of the darkness.

In the same paper, Hillebrand has investigated the law of mixtures, and has shown that the sum of the white valences of the components of a mixture is equal to the white valence of the resulting grey. This is a necessary consequence of any form of Hering's theory, and its verification is strong evidence in favour of that hypothesis.² It is not inconsistent with Young's theory, but appears quite inexplicable by it. On the other hand, the Law of Luminosities, *viz.*, that the luminosity of a mixed colour is equal to the sum of the luminosities of its components, a law often used to discredit Hering's theory, receives an easy explanation from Hillebrand's paper. For in the case, say, of a blue and yellow uniting to form green, just so much as the yellow constituent of the united colours increases the luminosity due to their white valences only, by so much does the blue constituent reduce it. Or, to put the matter otherwise: suppose we are combining the blue and yellow, the eye being rested, and the remainder of the field absolutely dark; then if we leave out the blue and yellow constituents entirely, we shall

¹ For the definition of the Valence (*valenz*) of a colour, see. *Zur Erklärung d. Farbenblindheit*, Prag, 1880, p. 6.

² Hillebrand, *l.c.*, p. 117.

affect neither the sums of the luminosities of the two colours separately nor combined.

As an argument against the older theory, the method used in these researches is even of greater weight than their results.¹ For, on Young's hypothesis there is no reason why the sensitiveness to white should gain relatively to colour sensitiveness for the rested eye, since it is entirely dependent on the sensitiveness to the three fundamental colours. But on Hering's theory, all objective colours having a white valence, the eye when open is under a constant stimulus as regards white, whereas the changes from colour to colour leave it, as regards these, in a relatively neutral state. Complete rest, therefore, helps the perception of white relatively to that of colour.

It only remains to be added, that the use of the method of extinction for calculating the white valence of a colour is confirmed by the examination of the totally colour-blind. Abney has noticed² in his recent work the agreement of the persistency curve with the luminosity curve of monochromatic vision. This had already been observed by Hering,³ and was predicted in Hillebrand's paper before he observed it.⁴

It is not too much to say that this paper of Hillebrand has converted the phenomena of colour mixture and the relations of the luminosities, in the compound and its components, from a difficulty and a reproach, into one of the chief strongholds of Hering's theory.

The next point that demands consideration is a criticism by Capt. Abney on Prof. M. Foster. He says, "Hering's theory is not properly trichromatic."⁵

A clear view on this point is very important. From the psychological point of view, no theory can be trichromatic. Psychologically considered, there are certainly five elementary visual sensations; or if, with both Hering and Helmholtz, we accept the positive character of the sensation of black, six. It might be contended that there were more, but there cannot be less. When, however, it is said that a theory of vision

¹ Hillebrand, *l.c.*, p. 113.

² Abney, "Colour Vision," p. 119.

³ Hering, "Untersuchung eines total Farbenblinden," Pflüger, *Archiv f. Physiol.*, Bd. x. p. 563.

⁴ Hillebrand, *loc. cit.*, p. 111.

⁵ Abney, *l.c.*, p. 57.

is trichromic, the proposition is not meant in a psychological sense,—the reference is wholly to certain experimental results of mixing colours together.

It is known, as a result of the study of mixtures, that a relation subsists, that a colour equation may be found, between any four colours taken at random, using the word "colour" in the extended sense, in which it includes white. This implies that from this point of view there are three independent colour variables, and a corresponding three-foldness in the perceiving arrangements of the retina.

Here, however, two paths emerge, according as we hold that pairs of colours combining to make white are complementary or antagonistic. On the first supposition, a negative quantity has no independent physiological significance, and can only be interpreted by transferring it to the other side of the colour equation; and this leads necessarily to some form of the Young-Helmholtz or three-nerve theory. On the second supposition a negative quantity has an independent physiological meaning, and is directly interpretable in terms of sensation; and this leads necessarily to a theory of triple pairs of sensations; in fact, to some form of Hering's theory. Whether such a theory is appropriately called "trichromic" or not, it is just as perfectly in accord with the experimental results of colour-mixture as its rival, and has the additional advantage of according with and interpreting the hexachromic character of the visual sensations given in perception.

Let us now consider the question of colour-blindness. But before examining Capt. Abney's criticism of Hering, let us look at the broad facts, especially in cases of colour-blindness from disease, or congenital colour-blindness in a single eye, and compare them with indications of the rival theories.

Now, on Young's theory it is obvious that, with the disappearance of any of the fundamental sensations, the sensation of white should vanish also. For the red-blind, white ought to be replaced by a blue-green-complementary to the fundamental red; and only greens and violets and the products of their combinations should remain. It receives no countenance in Abney's work. I leave out of account the suggestion of such large shifts of the curves of the elementary sensations as shall

lead to their fusion, which is the despairing resource of some recent supporters of Young's theory. So for other cases, and monochromatic vision should be of red, green, or violet, but never of white. On Hering's theory, on the other hand, the loss of a fundamental pair, red-green for instance, means a loss of saturation in, at any rate, part of the spectrum; and if accompanied by partial defect of the blue-yellow sensation, a loss of saturation would be observed throughout. In the supposed case the remaining colours would be blue or yellow. Cases of monochromatic vision would, on Hering's theory, usually be of shades of white or grey only.

This being premised, is it not a strong argument for Hering's theory that the facts are in general accord with these indications, and in complete disaccord with those of Young's theory; that in all cases of colour-blindness from disease, or of colour-blindness in a single eye, where the actual sensations experienced can be compared by the patient with those of normal vision, the defect of colour-vision is accompanied by a general loss of saturation in the spectrum; that in all such cases as yet recorded the remaining colours are blue and yellow (or in exceptional cases, blue only); that the combinations red and green, or red and violet, or green and violet, have *never* in any case been observed; and that the rare cases of monochromatic vision in a single eye,¹ or from disease, should be in absolute accord with the indications of Hering's theory? Is it not remarkable that, speaking broadly, in the peripheral part of the retina, red and green should be the first to disappear, then blue and yellow, and white alone should remain to the extreme verge² of the field?

From these broad and undisputed features of the case let us pass to Captain Abney's criticisms. He points out that in certain cases of tobacco amblyoma, blue was visible and not

¹ Abney, Case of Miss W., p. 161. The difference of the luminosity and persistency curves in this case is abnormal.

² See Hess, "Ueber d. Farbensinn. bei indirect Sehen. v. Graefe," *Archiv f. Ophthalm.*, Bd. xxxv. 4.

Abney's conclusions as to the exact limits of the blue and yellow fields are inconsistent with Hess, see p. 200; but he agrees that yellow continues after red and green have vanished, which, with other results obtained by Hess, is quite incompatible with Young's theory.

yellow, and puts this forward as a difficulty in the way of accepting Hering's theory. The alleged absence of yellow did not really occur in one of the cases given,¹ for the patient did perceive yellow at the red-end of the spectrum, though at the line D it appears to have been lost in white, but it seems to have occurred in the case of G;² but even in the case of G the blue was neutralised by light of wave length D, a clear indication that the light there had a yellow valence, though it was feeble compared with the white.

It is not, however, necessary that the blue-yellow substance should respond equally in both directions to the appropriate stimulus, more especially if the defect is due to disease.

In the case of normal vision, there are limits to the increase or decrease of the sensitive substance which it cannot overpass. As it approaches these limits it responds with increasing difficulty to the stimulus which is urging it.³ Now, it is not difficult to suppose that disease, without *directly* affecting the action of the stimulus, may affect very unequally these two limits; that the substance may be capable of increase but scarcely at all of decrease, and *vice versa*. For example, in the case of tobacco amblyopia, a probable hypothesis would be that while the red-green substance is completely destroyed, the blue-yellow substance is nearly so. This implies that during the course of the disease autonomous dissimilation has been greatly in excess of autonomous assimilation,⁴ and that they are only brought into balance when the sensitive substance has nearly perished. The condition of things somewhat resembles the condition of the normal eye after prolonged exposure to yellow light has nearly destroyed the power of perceiving yellow. In this case an increase of the yellow stimulus produces but a small effect, while a blue stimulus is at once perceived. On the other hand, while further changes in the amount of the sensitive substance are avoided, the two antagonistic stimuli may still be

¹ Abney, p. 151.

² P. 154.

³ See Hering's paper, "Zur Theorie der Vorgänge in der lebendigen substanz," *Lotus*, Bd. ix.

⁴ Autonomous dissimilation and assimilation are defined by Hering as the dissimilation and assimilation of the substance under its special conditions, uninfluenced by external stimulus.—*Lotus*, Bd. ix. p. 2.

effective to neutralise one another,¹ although, from the rapidly diminishing sensitiveness of the substance, and the strength of the white constituent of the sensation, the yellow valence of the light may be unable separately to assert itself in consciousness.

A second criticism of Captain Abney's relates to red-green blindness. "We are told,"² he says, "that both the red-blind and the green-blind are red-green-blind, and that the only difference between them is that the former has his spectrum slightly shortened at the red-end, the maxima of the yellow-blue sensations being shifted a little further towards the violet-end of the spectrum," and he asks why this shift occurs. Then assuming that Prof. Foster's explanation is meant to be exhaustive, he makes some critical remarks, which would in that case have great force.

Hering's explanation³ of these varieties of colour vision is entirely different, and depends (like that of Maxwell and others) on the varying depth of colouring-matter in different eyes, not only in the yellow spot but in the lens. That this is a real cause of such varieties, I think it is not possible for any reader of Hering's paper to contest. Whether, however, it is a complete explanation of the whole of them is more doubtful. If it is, Hering is compelled to assume a correlation between the depth of the colouring-matter of the eye and the strength of the red-green sensation, which appears to require independent verification. Moreover, if Hering's explanation is complete, Koenig's determination of the neutral points in the spectrum must be rejected as wholly untrustworthy; and though his method is open to some of Hering's criticisms, it is difficult to believe that the neutral line of all his cases was really identical.

If, however, Hering's explanation be rejected, the facts seem to be still more adverse to Young's theory than to his own. For on that theory the cases ought to be grouped about two different mean positions of the neutral line,—that of the green-

¹ For examples see "Vintschagen Pflüger," *Archiv f. Physiol.*, Bd. 97, p. 241; also Hering same vol. pp. 328-329.

² Abney, p. 192.

³ "Ueber individ. verschiedenheiten des d. Farbensinnes," *Lotus*, n.f., Bd. vi.

blind being nearest to the red of the spectrum. In complete disaccord with this, Koenig¹ found not only that the position of the line varied with each individual case, but he actually found a green-blind case at each end of the series. He himself draws the inference, unfavourable to the Young-Helmholtz hypothesis, which his work suggests.

I have referred above to the subject of peripheral colour-blindness. Some experiments on the matter are given in the appendix to Captain Abney's book. The subject has been investigated with great care by Dr Carl Hess.² He made quantitative experiments in a very ingenious manner by the use of the colour-top. His methods are, to a large extent, independent of the assumptions or conclusions of any theory. He found—

- (1) That there were four colours, a red, a green, a blue, and a yellow, which, while they gradually change in saturation as they are seen more and more excentrically, are unaltered in hue.
- (2) That these four colours form two "complementary" pairs.
- (3) That colour equations which subsist for the central parts of the retina (just outside the macula lutea), subsist also for the peripheral parts.
- (4) That all colours except the four mentioned alter in hue as well as saturation as they are seen more and more excentrically.

These results, which are independent of any assumptions, Hess and Hering³ have shown by the use of the colour-triangle to be inconsistent with the Young-Helmholtz hypothesis.

Hess found, also, that the visibility of a colour at the periphery

¹ Koenig, Wiedemann, *Annalen d. Physiol.*, N.F., Bd. xxii. p. 574. I give Koenig's list: G=green-blind, R red-blind, and λ is the wave-length of the neutral line in millimillimetres.

1. R λ = 491·7	8. G λ = 496·08
2. G λ = 492·04	9. R λ = 497·37–497·68
3. R λ = 492·25	10. R λ = 497·66
4. R λ = 493·08	11. G λ = 499·44
5. R λ = 495·8	12. G λ = 499·71
6. G λ = 495·92	13. G λ = 504·75
7. G λ = 496·01	

² Hess, "Ueber d. Farbensinn b. indirect sehen v. Graefe," *Archiv v. Ophthalmologie*, Bd. xxxv. 4. 1.

³ Hering, "Ueber die Hypoth. Z. Erklärung d. pereph. Farbenblindheit v. Graefe," *Archiv f. Ophthalm.*

of the retina was affected by the degree of its admixture with white light. Hence, in examining the extent of the colour fields, he chose colours which, tested by the methods of Hillebrand, appeared to have the same white valence. When this was the case, the fields for red and green were practically identical, as were those for blue and yellow. The determination of the fields for blue and yellow, requiring the use of very excentric parts of the retina, was far from easy, and required the use of colours of a low degree of saturation. It is therefore not surprising that Captain Abney,¹ using the saturated colours of the spectrum, has been led to results which appear to be inconsistent with those of Hess. It is undeniable that the general nature of Hess' results is highly favourable to Hering's theory.

Abney has suggested a modification of Young's theory which seems to require brief consideration. He suggests a separate mechanism for the perception of "fundamental light" in connection with each nerve of sensation, but he has nowhere defined the relation of this mechanism to the ordinary physiological antecedents of the perception of white. They are either identical or they are not. If they are identical, then it seems clear (especially in the light of Hillebrand's law of mixture) that the blue and yellow must neutralise one another, and that white is merely the emergence of the "fundamental light," or white sensation. In this case blue and yellow are not really complementary, but antagonistic; and Abney's proposal is not a modification of the Young-Helmholtz hypothesis, but a crude form of Hering's. If they are to be distinguished, then two entirely different physiological antecedents correspond to the same sensation of white,—a supposition so improbable that nothing but irresistible necessity could induce us to adopt it.

In conclusion, Hering's theory seems to rest on three foundations:—

1. On his analysis of visual sensations, and especially on his **view** of the positive character of black as a distinct sensation, **demanding** a distinct physiological explanation.

2. On Newton's Law of Colour Mixture, and the threefold **nature** of the visual mechanism which it necessitates.

¹ Abney, p. 208.

3. On the antagonistic nature of the so-called complementary colours.

The second foundation, which is a common pillar both of Hering's hypothesis and Young's, has been recently attacked, but the isolated experiments of Prof. Ebbinghans¹ and Mrs Ladd Franklin² on the mixture of complementary colours, with varying intensity of light, must be affected by some error. They are entirely inconsistent with Newton's Law, and that law rests upon such a long series of observations, and has formed the basis of so many verified calculations by illustrious men, that it cannot lightly be set aside; and Hering has repeated Ebbinghans' experiment with quite different results, and has pointed out possible sources of error.³

It is to the illustration and establishment, both directly and indirectly, of the third of these foundations that so much of the work of Professor Hering and his followers has been devoted. None of it has been more convincing than the discussion of simultaneous and successive contrast contained in Hering's original work; but in addition to that work, and to the papers already mentioned, I may be permitted to refer to two papers by Dr Carl Hess, who has shown⁴ that the changes which the spectrum colours undergo when observed by an eye which has been exposed to homogeneous light are inexplicable by any theory of mere retinal fatigue, and require just such a play of antagonistic forces as Hering's theory provides.

Throughout this note, language has been used which appears to imply the distinctness of the three elementary substances. It is, however, to be noted that this is not an essential of Hering's theory. A single sensitive substance, capable of manifold assimilative and dissimilative changes, which can be thought of as resolved into three principal components, is all that is necessary to the hypothesis,⁵ and it may tend to lighten

¹ Ebbinghans, "Theorie d. Farbensehens," *Zeitschrift f. Psychol. u. Physiol. d. Sinnes Organe*, Bd. v.

² C. L. Franklin, *Mind*, vol. ii. p. 487.

³ Hering, "Ueber d. Einfluss d. Macula lutea auf spec. Farbengleichungen," *Pflüger, Archiv*, Bd. liv., p. 277.

⁴ Hess, "Ueber die Tonanderungen der Spectralfarben, etc." V. Graefe, *Archiv f. Ophthalm.*, Bd. xxxvi. 1, also Bd. xxxix. 45.

⁵ Hering, in the preface to Hillebrand's paper, p. 73.

some difficulties which have been raised if we remember that, owing to the important part played by the changes to which the sensations of grey are due, and to the dissimilative character of the only colour, red, which has a relatively feeble white valence, it is fairly certain that every external stimulus produces on the whole a dissimilative and destructive effect upon those parts of the perceiving apparatus upon which it directly acts, and an average destructive effect even when the whole organ of vision is considered. When due weight is given to this last consideration, it does not appear probable that recent attempts to set aside Hering's theory as physiologically absurd will achieve success; nor will it seem inherently incredible that the play of creative and destructive forces, which is the characteristic of living tissue, should have been utilised in a special substance, as the immediate antecedent of those sensations of light which are the crowning marvel of sentient life.

NOTE ON THE STEREOPHOTOCHROMOSCOPE—A NEW
OPTICAL INSTRUMENT. By DAVID FRASER HARRIS,
B.Sc. Lond., M.B., C.M. Glasgow, *Second Assistant to the
Professor of Physiology, University of Glasgow.*

I HAD lately, in London, the opportunity of examining, through the kindness of Mr Ward, who is acting for the inventor, Mr Frederick E. Ives of Philadelphia, an instrument of great interest to physiologists, inasmuch as it has been devised upon data directly deducible from the Young-Helmholtz theory of Colour-Vision.

The *stereophotochromoscope* is the product of a research by a physicist and photographer, who has solved one aspect (at least) of the problem of "photography in colours." Mr Ives does not, indeed, execute a coloured photograph on a card—and in this sense has not solved the problem of "photography in colours"—but he has constructed an instrument wherein we can reproduce in a mental picture the objects of the world around, not only in all their solidity, but, with a fidelity that is absolutely startling, their colours, tints, lights and shadows. Since, however, the novelty is not in its stereoscopic but its chromatic features, I need here only say that the essence of the process for reproducing coloured objects is, in the first place, the stereoscopic photographing of the coloured object; and secondly, the viewing of these photographs in coloured lights and under such optical conditions as to give the illusion¹ of a solid, coloured body.

There are, then, *two* instruments: a photographic camera for stereoscopically photographing the coloured object—as, for example, a basket of fruit and flowers; and secondly, the

¹ It must be premised that I use the term "illusion" as a technical term for a mental impression where the judgment predicates more than unaided sensation could warrant.

stereophotochromoscope proper—in which the photographs are submitted to inspection.

For a reason to be given immediately, *three* stereoscopic *pairs* of photographs of the one coloured object are taken by a single exposure on one sensitive plate.

Thus there are six negatives in pairs (each pair being sometimes called a “stereogram”): positives of these are then made in the usual way by “developing” and “printing” upon glass; the set of transparencies being then known as a “chromogram”; for, as will presently be explained, these photographs are records of colour-effects.

As the paired photographs are not to be all examined in one plane in the photochromoscope, the three pieces of glass, each with its double transparency, are hinged together by a flexible material to permit of chromatic illumination in three different planes.

The essence of the Young-Helmholtz theory of colour-vision is that in the retina we must suppose *three* sets of end-organs, of such constitution that one set responds most energetically to light at the red-end of the spectrum, less so to greenish light, and least of all to violet; that the second set are most irritable in green light, less so in light at the extremities of the spectrum, while the third set is most susceptible in violet light, less so in greenish, least of all in reddish light. The sensation of white light is produced when all the three end-organs are excited in nearly equal degrees.

Now, it is known that it is not only pure spectrum-red rays that excite the fundamental sensation of “red” (consequent upon stimulation of what we have called the first set of retinal nerve-endings), but that the “red”-sensation is produced by all the spectrum-rays from red to green, though most powerfully by the orange; similarly, the “green”-sensation is produced not only by spectrum-green, but by the simultaneous action of orange, yellow, yellow-green, green and green-blue (all of which rays act with varying energy on the so-called “second set” of nerve-endings); and lastly, the violet-sensation is the result of the simultaneous action of the several rays, from the green-blue to the violet extremity of the spectrum. Thus, although it is true that the three “primary” colours are red, green, and

violet, yet this must only be taken as a succinct statement of the Young-Helmholtz theory ; for while spectrum-rays of one colour will serve to *represent* chromatically the corresponding fundamental colour-sensation, yet it is a physical fact that several widely-separated rays, *i.e.*, lights of very different colours, can excite in any one normal person one and the same fundamental sensation. We can, therefore, map out in the solar spectrum three curves, the height of each being a measure of the power of the different rays to excite their respective colour-sensations, and the area enclosed by each curve being a graphic representation of the entire group of rays, which, when simultaneously acting, yield a particular fundamental colour-sensation.

Thus any of the rays from red to yellow can excite, in varying degrees of intensity, the red-sensation, and all those rays acting together give the full fundamental sensation ; but when we represent by a colour what this sensation is, we indicate it by light somewhere about the C line. And similarly for the other sensations. In fact, there is a difference between all the actual coloured rays, efficacious in producing a colour-sensation, and the chromatic representation of that fact of consciousness by a light of one definite colour.

The place of these rays in the spectrum, their relative sensation-producing power, and their relative amount of actinic influence, are physical facts ; so that, following the data given by Maxwell, König, and Abney, one can, to use Mr Ives' own words, "by the photometric measurement of the density-curve of a spectrum negative" find the relative amount of reaction by the different spectrum rays. "It is therefore," he continues, "only necessary, in order to secure action by different rays in any definite proportions, to use such a combination of sensitive plate and colour-screen as will yield a spectrum negative having a density-curve corresponding to the graphic curve representing such proportionate action."¹

Let us call the three paired photographs or stereograms A, B, and C ; the negative of A was taken by interposing between the object and the sensitive plate a glass of such colour (yellow-orange) that only those rays capable of exciting the fundamental red-sensation acted on the plate, in the case of B the light which

¹ *Journal of Society of Arts*, May 27, 1892.

had passed through an aniline-yellow glass was such as affected only the fundamental green sensation ; and C was illuminated, in its turn, by such rays as excited only the blue-violet-sensation, this being brought about by the use of a green glass selective screen.

We have really, therefore, not merely three stereograms or "positives" of stereoscopic photographs (which in themselves, viewed by daylight, show no colour, but are like ordinary positives from negatives taken in daylight), but we have three such records of the natural colours of the object, that in order to reproduce these to the eye, it is only necessary to superpose upon the retinae the three triple images illuminated in the following way—that representing the effect of the fundamental "red"-sensation with pure red light (of wave-length as at line C), that representing the green-sensation with pure green light (wave-length E), and that representing the blue-violet-sensation with pure violet light (about wave-length G). This *blending* of the three images lit by the three "primary" coloured-lights, *i.e.*, the colours characteristic or representative of the three sensations, will excite exactly the same colour-sensations as did the polychromatic light coming directly to the eye from the object itself.

Thus, in the chromogram, A is a photographic record of all entirely red things and of such parts or points of any other things that reflected, scattered, or in any way transmitted red or allied light to the camera : the glass used as a selective colour-screen was not red (for red things looked at through a red glass are not red but whitish), but yellow-orange tinted glass, through which red things look most intensely red. Analogously for the other colours : B is a record of all things and all parts of things that in any way transmitted green or allied light to the camera, and C is such for the violet. A "primary" colour is one which cannot be made by combining any other coloured rays : red, green, and violet, or, in popular terms, vermilion, emerald-green, and ultramarine, are these colours, and with these we can form white light, and every possible colour, with all intermediate shades and tints of nature, not excepting the "saddest" of æsthetic hues. Thus every point of the object is represented somewhere in the chromogram, and the light it originally

reflected is now provided to illuminate it: if it originally reflected only one kind of coloured ray—a primary—it can find that light again to tint it; if it reflected two or three kinds of rays, they are all there again for simultaneous treatment by it. The crucial test is in the case of colours not present as such in the spectrum, *e.g.*, the *purple* of plums or grapes: the photographs of these objects are combined into *one* image, as of solid plums or grapes, now lit simultaneously by both red and violet light—a fusion which produces the sensation of purple; and so on for all other shades and tints of colour. To quote Ives' words—"The three images of the chromogram represent the action of all incident light upon the respective fundamental colour-sensations, and the light by which each image is illuminated in the lantern or heliochromoscope represents the sensation itself." This is the gist of the whole matter: the "heliochromoscope" is the older name for the stereophotochromoscope, and by it a single image may be thrown on a screen instead of the double one into the eyes. Of course, when so projected on to a flat surface and viewed with the naked eye, as in a lantern demonstration to a large number of people, the illusion of solidity in the coloured picture is entirely lost, that being an effect due to optical contrivances produced by its very nature only in the brain of each individual looking into the instrument. While using the projection-lantern, the whitest of light—that of the electric arc if possible—must be employed, when the results are very satisfactory.

To those conversant with the practical details of photography, a criticism will at once suggest itself:—How can the three chromograms be taken simultaneously on the one plate, seeing that the time of exposure for red light is much longer than for any other colour? This is a difficulty which the inventor overcomes in two ways: he either reduces the intensity of the other two more active colours by interposing "ground" or smoked glass in the path of their rays, or he employs a larger diaphragm for the "red" light than for the "green" or "violet."

What strikes one on looking into the stereophotochromoscope is the brilliance or vividness of the colours of the object—an appearance partly due to the image being seen against a dark background, and partly to its being reduced, or less than "life".

size: it is for this latter reason that the inverted image of a coloured object, sharply focussed on to the ground-glass plate of the camera, looks so clear and bright.

I have hitherto purposely omitted all reference to the purely optical contrivances in these two instruments. In the stereoscopic camera they are the outcome of extensive knowledge of chemistry, photography, and chromatics; in the other instrument, of as practical an acquaintance with both physical and geometrical optics. In the Photochromoscope, in order to cause coincidence upon the retina of the three coloured images, there are employed, besides the pure colour screens, objective-glasses and eye-pieces, seven mirrors—4 of silver, 3 transparent; each coloured ray undergoing at least three plane reflections before reaching the eye.

In a physiological laboratory this instrument will be of great value in demonstrating the physical data of the Young-Helmholtz theory of colour-vision; while it will be used by scientific physicians who desire to have a more accurate record than even an artist can give them of the colours and hues of lesions in skin diseases.

To the ethnologist, anthropologist, geographer, and scientific explorer it will also be of great service, while the value of any invention that would give a record of personal chromatic characteristics would be great in the Criminal Investigation Department.

ON THE EXTERNAL CHARACTERS AND SOME PARTS
OF THE ANATOMY OF A BELUGA (*Delphinapterus
leucas*). By JOHN STRUTHERS, M.D., LL.D. (PLATE IV.)

THIS Beluga was found alive in the salmon-fishing nets at Dunbeath, Caithness, on 26th April 1884, and by the active kindness of my pupil, Mr Adam Mackay, was secured for me and sent on to Aberdeen, where it arrived on the 30th in good condition.¹

Parts noticed, and Order.

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¹ From Mr Mackay I received graphic particulars of the capture and activities of the Beluga. It was still alive when he wrote to me, and lived for eight hours after the capture. Apparently in pursuit of the salmon, it had made its way into the inner chamber of the salmon nets at the mouth of the river, where it was found imprisoned in the early morning. It was secured with difficulty by a rope round the tail and a "clip" in the blow-hole, and thus towed to the shore, during which proceeding it nearly succeeded in towing the boat out to sea, and blinded the fishermen with the shower-bath from its blow-hole. It was then fastened to a ring in the wall by a long rope, 240 feet long, round the tail, giving it freedom to disport itself in the shallow water at low tide, during which operation it made repeated efforts to get to sea, nearly pulling six men into the water, and in subsequent efforts to get to sea strained the strong rope to the utmost. In the absence of the men, the boys of the place amused themselves by teasing it, making it "frantic," and it uttered low moans like the grunting of a pig, but not so shrill. In frolic the boys changed the fastening to a boat, and in fear of

(A) EXTERNAL CHARACTERS.

Measurements.—Some of the following measurements may appear unimportant, but I give them as the opportunity was a favourable one for taking them accurately in a fresh condition.

	Feet.	Inches.
Total length, straight, to back of tail-fin,	12	5
Length to same, following the undulations of the back,	13	...
<i>Tail-fin.</i>		
Tip to tip,	2	9
Depth of cleft, . . . . .	...	4
Breadth, greatest, near cleft, . . . . .	...	12
„ at middle of each lobe, . . . . .	...	9
„ at half way between middle and tip, . . . . .	...	6
<i>Pectoral fin.</i>		
Length, along middle, to tip,	1	4
„ along curve of anterior border,	1	6
„ „ of posterior border,	1	4
„ from where anterior border joins body, straight, to tip,	1	5
„ from where posterior border joins body, straight, to tip,	1	2
Breadth at junction with body, . . . . .	...	6
„ at half way to middle, . . . . .	...	8
„ greatest, $\frac{1}{2}$ inch in front of middle, . . . . .	...	10 $\frac{1}{4}$
„ at half way from middle to tip, . . . . .	...	6
Thickness, greatest, at middle of proximal half, and a little in front of middle line of fin, . . . . .	...	2
Length from angle of mouth to pectoral fin,	2	...
Height from pectoral fin to ridge of back,	1	6 $\frac{1}{2}$
<i>Head.</i>		
Angle of mouth to angle of eyelids, . . . . .	...	3
Opening of eyelids, length, . . . . .	...	1
„ „ height, . . . . .	...	$\frac{3}{8}$
From opening of eyelids to ear-hole, . . . . .	...	6
Mouth, point of lower jaw to angle, . . . . .	...	9
Projection of upper jaw beyond lower, . . . . .	...	$\frac{3}{4}$
Point of upper jaw to cushion of forehead, . . . . .	...	5
Blow-hole, from point of upper jaw, straight,	1	2 $\frac{1}{2}$
„ „ „ along the curve,	1	6
„ behind vertical line from eye, . . . . .	...	3

its escape stabbed it in the belly. Much blood was lost, and the beluga became very restless and moaned continuously. On the return of the fishermen from their nets, it was hauled up on the beach above tide-mark, and died two hours after it had been stabbed.

The beluga was carted to Wick, a distance of 21 miles, on the 29th, and at once shipped for Aberdeen, where I received it next day, and removed it to the anatomical rooms. It was in quite fresh condition ; photos were immediately taken and the measurements made.

	Feet.	Inches.
Transverse diameters and circumferences, mouth closed :		
At middle of mouth, diameter,	...	6½
" " circumference (excluding lower jaw),	2	1
At angle of mouth, diameter,	...	9½
" " circumference,	3	2
At the eyes, diameter,	1	1
" " circumference,	3	6
At the ear-holes, diameter,	1	1¾
" " circumference,	3	9
At blow-hole, midway between eye and ear-hole, circumference,	3	8
Eye to eye over top of head,	1	9½
Ear-hole to ear-hole over top of head,	1	10½
<i>Body (between head and tail-fin).</i>		
Transverse diameters and circumferences :		
At just above pectoral fin, diameter,	1	7
Circumference just before pectoral fin,	5	1
" " behind "	5	5½
At thickest part of body (5 feet from point of jaw and 2 feet behind pectoral fin), diameter,	2	...
" " circumference,	6	½
At 6½ feet from point of jaw, diameter,	1	10
" " circumference,	5	4½
At 4 feet from back of tail-fin, diameter,	1	½
" " circumference,	3	4
At 3 feet " diameter,	...	8
" " circumference,	2	7
At 2 feet " (1 foot in front of lobe of tail-fin), diameter,	...	4½
" " circumference,	2	...
At narrowest part (4 inches in front of tail-fin), diameter,	...	3¾
" " circumference,	1	5
<i>Position of the anus :</i> from back of tail-fin,	3	5
From posterior edge of pectoral fin, at junction,	6	...

Form.—Referring to the figure (fig. 1), the following elevations and concavities are seen on the *dorsal* outline. *At the head*;—A well-marked wide concavity, $\frac{3}{4}$ inch in depth, corresponds to the neck, and marks off the head. This cervical concavity remains distinctly present in all positions of the head. On the head two elevations are seen: the posterior, the highest part of the head, is the blow-hole eminence; the anterior, or “forehead” prominence, rounded, is a cushion of fat. Between it and the blow-hole eminence is a moderate concavity; below it is a sharper concavity, sloping rapidly to point of the jaw or lip. The projection of this cushion gives the “forehead” appearance and the blunt form to the anterior end of the head.

On the *body*, including its caudal prolongation to the beginning of the tail-fin, are seen two convexities: (1) The anterior extends from the cervical concavity backwards fully to the middle of the entire carcase, its thickest part. This long convexity, rising $2\frac{1}{4}$ inches from the level of the concavities before and behind it, is the part which, or a portion of it, has been regarded as a rudimentary dorsal fin, to be noticed below. Behind this long convexity the line of the back falls rapidly down, forming a wide concavity, $1\frac{1}{8}$ inches in depth, as far as to opposite the anus. (2) The posterior convexity, less prominent, begins here and corresponds to the caudal region of the spine, and goes back upon the caudal fin half way to the cleft, as the sharp upper ridge of this laterally compressed region of the carcase reaches upon the caudal fin to that extent.

Rudimentary dorsal fin, or protuberance.—It is well to avoid using the name “dorsal ridge” for this part, as that term has a general application. This part has been regarded as a rudiment of a dorsal fin, though Beluga cannot be said to have a projection giving the appearance of a dorsal fin.

Of this part Mr Neill,¹ describing the external characters of the 13 feet 4 inches-long male beluga, of which Dr Barclay describes the dissection, says: (p. 373) “On the middle of the back, as in other whales, there was a longitudinal ridge, partly bony, partly soft”: and (p. 374) “The hard part of the dorsal ridge measured in length 1 foot 4 inches; and the soft part extended nearly 3 inches farther at both extremities.”

It is thus described by Professor Lilljeborg, of Upsala, in his short notice of Beluga:²—“There is, on the middle of the back, as a rudiment of a dorsal fin, a longitudinal, rough, compressed protuberance, about 18 inches long, formed by the skin, on which the epidermis is much harder than elsewhere.” But he adds that his description, which appears to have been from a $10\frac{1}{2}$ feet-long female, is “from a salted skin from Greenland, of which the head, the hind part, and the fore extremities were uninjured.”

In regard to these appearances, I have no note of any part of **this** long convexity being rough or hard, though I was examin-

¹ “Account of a Beluga or White Whale, killed in the Firth of Forth, by Dr Barclay and Mr Neill,” 1815. *Memoirs of the Wernerian Natural History Society*, Edinburgh, vol. iii.

² *Synopsis of the Cetacean Mammalia of Scandinavia (Sweden and Norway)*, 1861–62. Ray Society, London, 1866. Edited by Sir W. H. Flower, p. 242.

ing the parts carefully. There was no definite beginning or ending to the convexity, composed of skin and blubber, and over 2 feet is a long base to assign for a rudimentary dorsal fin in an only $12\frac{1}{2}$ feet-long cetacean. On the other hand, even in up-standing dorsal fins there is no sharp limit at the base. What I noticed here, not referred to by the authors above quoted, was a very marked *groove* at each side of the eminence, seen from the side as well as from above. From the top of the convexity to the bottom of the groove, along the sloping side of the eminence, is 5 inches. This ditch on each side suggests the idea of a special fin-like projection, but the groove is continued all the way back on the caudal region too, at about 3 inches down from the median ridge. The meaning of this long bilateral groove, extending all along the dorsal, lumbar, and caudal regions of the spine, may, perhaps, be found on examination of the processes of the vertebræ or of the muscles upon them.

The *general form*, as represented in figure 1, gives much less height at the middle third in proportion to the length than in the figure given by Neill and Barclay, well-known from being reproduced in Bell's *History of British Quadrupeds* and other works. It was from a sketch by an artist.¹

I have made due allowance for the compression at the abdomen from the position of the carcase when the photographs were taken, and, with that addition to the convexity below, give the figure as a true representation of the general form of this beluga.

Colour.—The young beluga is said to be at first mottled greyish-brown, then becoming entirely white. This beluga is pure milk-white throughout, a beautiful creature. The thin posterior edge of the pectoral fin and thin posterior edge of the tail-fin are apt to become dusky from drying. When the outer epidermis has been detached in patches, or cuts made into the deeper epidermis, the exposed parts become reddish after a time, and this might mislead.

¹ Their figure, judging by my beluga, is too swollen at the middle, both the ventral and dorsal lines too bulging, too artistically uniform. There is no distinction of curvatures of the back behind the cervical concavity, and the distinctive form of the caudal region of the body is not indicated; nor is the distinction between the forehead cushion and the blow-hole eminence shown,—the latter, indeed, is not indicated at all. In their figure the greatest height is to the length as about 1 to 4, in mine it is as about 1 to $5\frac{1}{2}$.

Skin.—Little need be added to Dr Barclay's account of the skin.¹ In this beluga the deep soft epidermis, seen through the thin outer epidermis, is about $\frac{1}{3}$ inch thick; at the top of the dorsal protuberance rather thinner, at the dorsal groove thicker ($\frac{5}{12}$). On raising the epidermis, close-set fine filaments are seen entering it from the cutis vera, like filiform papillæ; the deepest part is striated vertically, and has a pink tint near the cutis, increased to red on exposure; the outer part of the soft epidermis is pure milk-white, and tends to stratify transversely. Cutis vera $\frac{1}{10}$ to $\frac{1}{8}$ inch in thickness.

Blubber.—The blubber was about an inch thick, not different from that of other cetaceans, a jelly-like mass, firm enough to keep its form, and of cream-yellow colour.²

Fatty cushion of the forehead.—This large soft mass is seen to be 4 inches in depth, 3 inches of it blubber, the deeper part the origin of a strong muscle, radiating forwards into the cushion and upwards and backwards towards the respiratory passages.

On longitudinal and transverse section, the cutis vera between the blow-hole and the cushion appears greatly thickened, looking like a cap on the head, 2 inches thick behind, diminishing forwards to the front of the cushion; in longitudinal section like a sickle, in transverse section like a crescent. This fibrous cap, however, is but the transition from cutis to blubber, giving the blubber a strong stringy connection to the cutis. Then comes the usual soft blubber forming the bulk of the cushion, through which the tendinous continuations of the radiating muscle pass to be attached to the cutis of the cushion and the fibrous cap. This muscle will have the action of keeping the fatty

¹ He notices the distinction between the thin outer epidermis, thin as writing-paper, transparent when dried, becoming opaque when moistened, and the deeper epidermis, as if of two layers of equal thickness, together rather more than $\frac{1}{3}$ inch thick; the outer stratum white as milk, and without fibrous or membranous structure; the deeper stratum darker, vertically-fibred and irregularly laminated.

² Mr Neill says the blubber was "in general about 3 inches thick"; Dr Barclay says "in several places, some inches deep," and "of a greenish colour, arising from a fluid and limpid oil, that, instead of adeps, was here diffused in large quantities, through that part of the cellular texture interposed between the cutis and muscles," and he likens it to the green fat of the turtle. This condition of the blubber was probably owing to putrefaction, the fat-cells decomposing and allowing their contents to escape. In beginning his account of the dissection he mentions "the putrid state of the body." Their beluga may possibly have been in better condition than mine. Theirs was killed early in June, mine near the end of April.

cushion firm on the head, besides any action its posterior bundles may have on the walls of the respiratory cavities at and below the blow-hole.¹

Ear-hole and passage.—The aperture of this very interesting vestige, though very small, was easily recognised in the usual position, on a line from the eye to the attachment of the pectoral fin, here 6 inches behind the eye. It is seen in the figure as a minute point in that position. The *meatus* goes straight in for $1\frac{1}{2}$ inches, with soft walls, easily dissected from the surrounding blubber; then follows a cartilaginous stage, about $\frac{3}{4}$ inch. The meatus has two rounded-off rectangular bends, one where the two stages meet, the second on the cartilaginous stage, giving a sigmoid course. Tissue to the naked eye extremely like longitudinal muscular fibre, round the first stage, was found on examination with the microscope to be only blood-stained fibrous tissue.

Perineum.—The parts seen at the surface here are:—From behind forwards, mesially, the anus; 6 inches in front of the anus the vagina, but the vulva begins immediately in front of the anus; orifice of urethra; then for 3 inches the clitoris; then the blind fissure of the vulva for 9 inches. Laterally, the

¹ *Muscles, spiracular cavity and its sacs.*—I had not time to examine these parts fully, but may mention what I noted. These parts have been fully described by Dr Murie in *Globicephalus melas* in his elaborate and valuable memoir on that species (1867, *Trans. Zoo. Soc.*, London, vol. viii.), and I compared what I saw in this beluga with his figures of the muscles. I did not see any longitudinal muscle here, such as those figured by Dr Murie (N, *l*, fig. 63, and N, *l*, 1, 2, fig. 64), but saw the lateral muscle (L, *l*, *s*, *a*, *n*, fig. 64, or L, *s*, *p*, fig. 65) passing upwards and inwards towards the blow-hole and spiracular cavity, in continuity with the radiating muscle above noted.

As the *sacs* connected with the spiracular cavity appear to vary in different species (in regard to which see the Memoir of Dr Murie above referred to), I note what I saw of them in Beluga, without giving names implying their homology. Blow-hole; crescentic opening, concavity forwards, $2\frac{1}{4}$ to $2\frac{1}{2}$ inches measured straight. Two pair of *sacs* opening from spiracular cavity. *First pair.*—Apertures about $1\frac{1}{2}$ inch in size, and about 2 inches apart, proceed from fore part of sides of spiracular cavity; length of sac $3\frac{1}{2}$ inches, breadth about 3 inches, retaining size apparently to blind end; directed downwards, outwards, and forwards. These sacs lie at $1\frac{1}{2}$ inches from the skin, and upon a muscle similar to that referred to above as marked L, *l*, *s*, *a*, *n*, in Dr Murie's Memoir on *Globicephalus*. *Second pair.*—Deeper, close to surface of bone, lower boundary of aperture is the edge of the bone; length about 3 inches, breadth $2\frac{1}{2}$, extend crescentically on outer side of nasal aperture, shape like hoof of ox. Only thin septum between them, formed by meeting of their transversely-ridged mucous membrane.

mammary fissure is seen $1\frac{1}{2}$ inches from the vulva and opposite the vagina; the right $2\frac{1}{2}$, the left 3 inches in length, but the nipples are of equal size. Other longitudinal fissures are seen; one an inch external to each mammary fissure, and of about the same length as it; one an inch internal to each mammary fissure; and, on the right side only, one between the latter and the mammary fissure. Those internal to the mammary fissure are shallow, that external to the mammary fissure is deeper but blind. The umbilicus is 3 feet 4 inches in front of the anus; appearing as a firm depression, with a fissure before and behind it, each some inches in length.

(B) DISSECTION AND ANATOMY OF SOME PARTS.

My notice of the viscera is unavoidably scanty.¹ That is the less to be regretted as we have a full and valuable account of the viscera of Beluga by the late Professor Morrison Watson and Professor A. H. Young, of Manchester, in their account of the dissection of an 8 feet $7\frac{1}{2}$ inches-long female beluga.² Their account relates chiefly to the visceral anatomy, touching little on the points chiefly considered in this paper. In regard to the viscera, I notice only what I noted before removing them to the museum, and in so far as I find that what was noted differs from their account or occasionally supplements it. Had I seen their account before making the dissection my attention would have been directed to points in comparison.

Intestines.—No cæcum; intestine diminishes backwards to rectum, this perhaps from early part being full and later part empty, but

¹ In apology for that, and for the unequal treatment of the anatomy of the several parts of this beluga, I desire to mention that the dissection was made under great pressure for time, the beluga having come in when I was engrossed with teaching. I had no choice but, after a rapid examination of the viscera, to transfer them to the museum, in the hope of finding leisure for further examination of them. The following parts of this beluga were placed in the Anatomical Museum. The skeleton; sections of the skin and blubber at the rudimentary dorsal fin and groove, and at other parts; antero-posterior sections of the tail-fin; perineum, showing the mammary and other fissures; pelvic bones with surrounding parts; the eyes; the ears, external, middle, and internal; heart with great vessels; larynx with trachea and lungs; tongue; stomach; portions of intestine at several stages; left kidney; uterus, ovaries and broad ligaments.

² "The Anatomy of the Northern Beluga, compared with that of other Whales," *Trans. Roy. Soc. Edin.*, vol. xxix., 1879.

seems natural. Length 91 feet. Transverse folds of the mucous membrane, like *valvulæ conniventes*, along first half of intestine numerous and large, but about middle of entire gut have become not quite so numerous or so large; at about midway between this and the end, they are faint but numerous; within 12 inches of anus, no *valvulæ*, mucous membrane smooth.

The length of the intestine was found by Professors Watson and Young, in their 8 feet $7\frac{1}{2}$ inches-long beluga, to be only 54 feet; by Dr Barclay, in his 13 feet 4 inches-long one, $85\frac{1}{2}$ feet. That is, in both, a proportion to the total length of the animal of about $6\frac{1}{3}$ to 1; while, in my 12 feet 5 inches-long one, the proportion would be about $7\frac{1}{3}$ to 1.¹

An interesting point is the extensive occurrence of folds of the mucous membrane in the *transverse* direction,² and appears to contrast with the arrangement of the folds mostly in the *longitudinal* direction in the *Balænoptera*. In the $14\frac{1}{2}$ feet-long *B. rostrata* I dissected in 1870, the whole $67\frac{1}{2}$ feet of the small intestine had extensive foldings of the mucous membrane; along the upper $\frac{2}{3}$ the longitudinal folds, 6 or 7 in number in the breadth of the slit-open intestine, had secondary transverse wavings; in the lower $\frac{1}{3}$ the transverse foldings predominated, forming a close succession of transverse plaitings. In the dried

¹ Much depends on the way the intestines are measured. When tried along the gut as convoluted, the proceeding is uncertain; when done with the intestines laid out on the table, a good deal depends on the closeness with which the mesentery has been cut off. But, not unaccustomed to guard against the latter source of error, I found 91 feet to be the fair length of the intestine in my beluga.

² They are more exactly described by Professors Watson and Young (*loc. cit.*, p. 405) as beginning to appear 1 inch beyond the point of entrance of the combined hepatic and pancreatic ducts. "At first small and faintly marked, they rapidly become *valvulæ*, and form circular valve-like projections, measuring $\frac{3}{4}$ of an inch in depth, attached to the entire circumference of the gut. These large folds alternate with others of smaller size, which do not extend round the entire gut. The larger *valvulæ* are found along the upper half of the intestine, but below this they become smaller and less regularly disposed. In the lower 9 feet of the gut they are scarcely recognisable." This description might almost pass for that of the arrangement of the *valvulæ conniventes* in the small intestine of man, in whom they diminish along the third quarter, and are usually absent in about the last quarter, more or less, of the length of the small gut, but nowhere going entirely round.

Dr Murie (*op. cit.*, p. 289) notes the arrangement of these folds in *Globicephalus melas*: Intestine 97 feet 4 inches in length, being 9 times the length of the animal. *Valvulæ conniventes* seen as "great transverse folds" for first 6 or 7 feet, beginning in lower part of duodenum; continue along about next 36 feet, uninterruptedly but becoming smaller; then show reduction, with partial longitudinal and oblique intersecting folds; then for 40 feet or more, longitudinal

and distended preparations taken from the several stages of the small intestine of that *B. rostrata*, neither longitudinal nor transverse ridges appear; but the transverse folds in the dried colon, beginning faintly in the cæcum, are very fully seen, as both the valvulæ conniventes of the small intestine and the crescents of the colon are in dried and distended preparations of the human small intestine.

This appears to raise a doubt as to whether these folds in the cetacea do not belong only to the collapsed or empty condition of the small intestine. This question had been before the thoughtful mind of John Hunter, and he had concluded that the folds do not entirely depend on the action of the muscular coat.¹

But that these marked foldings of the cetacean intestinal mucous membrane do not depend on the state of the muscular coat at death or on the full or collapsed state of the gut, will be evident when we reflect that valvulæ conniventes are not seen in the lower part of the human ileum in any of its conditions, nor in either the jejunum or ileum of quadrupeds. When I had these numerous and marked foldings in *B. rostrata* before me I

folded the most marked, running in pairs, nearly parallel but sinuous, united by short transverse folds; within about 3 feet of anus, the longitudinal parallel folds increased in size, the short transverse and oblique rugæ relatively diminished.

On this interesting point in the anatomy of the cetacea, Sir William Flower remarks, in his "Lectures on the Comparative Anatomy of the Organs of Digestion in Mammalia" (*Medical Times and Gazette*, October 1872, p. 428), of the toothed cetacea:—"The absorbent lining surface of the small intestine is vastly increased by prominent folds or ridges, formed as the valvulæ conniventes in man, but more longitudinally instead of transversely"; and of whalebone cetacea:—"The lining membrane of the alimentary canal has always some arrangement for increasing its surface, either by transverse or longitudinal folds. These attain their greatest degree of complication in the long-finned, or hump-backed, whale (*Megaptera*), where there is a cellular structure something like that of *Hyperoodon*."

¹ "Observations on the Structure and Economy of Whales," *Philosophical Transactions*, 1787; more accessible in the reprint in *Palmer's ed. of the Works of Hunter, with Notes by Owen*, 1887; see vol. iv. p. 360. Of the arrangement in *B. rostrata*, Hunter says ("Essays and Observations," edited by Sir Richard Owen, 1861, vol. ii. p. 115), "The inner surface of the duodenum is thrown into longitudinal rugæ or valves, which are at some distance from each other, which receive lateral abutments. The inner coats of the jejunum and ileum are thrown into irregular rugæ, which will vary according as the muscular coat of the intestine acts; yet I do not believe that their form entirely

noted that they appeared to increase the surface much more than the valvulæ conniventes do in man, in whom they may be reckoned as doubling the surface. The occurrence of these foldings in one or other form is a remarkable feature in the cetacean œconomy. Their occurrence in man, in contrast with quadrupeds and anthropoids, may be regarded as an adaptation to the erect posture; in the cetacea the adaptation may be put more generally, as giving a less projecting abdomen, offering less resistance to locomotion in water.

Kidneys.—In Professors Watson and Young's beluga, they were 9 inches in length, with average breadth of $3\frac{1}{4}$ inches. In this larger beluga, they have, length 17 inches, breadth $5\frac{1}{2}$, thickness $2\frac{1}{2}$, and weighed 4 lbs. 4 oz. each. Supplied by two large arteries, one in front, one behind. There was a large thick-walled chronic abscess, as large as the kidney, between the right kidney and the lumbar wall, but unconnected with the kidney, which had the same size and weight as the left. The posterior artery passed through the abscess.

Lungs.—As very general in the cetacea no division into lobes on the surface; but, on inflating the accessory bronchus of the right and the early bronchial branch of the left, an isolated anterior part of each lung is distended, about 12 of the 26 inches of the length of the lung on the outer side. The raised border limiting the inflated part has the same direction as the great fissure of the human lung, *i.e.*, what would be downwards and forwards in the human body. This seems to show that there is no communication between the divisions of the accessory bronchus and those of the chief bronchus. In collapsed condition, lungs wrinkled on surface. Pleura easily raised and dissected off with handle of scalpel; the portions thus raised very elastic. There is some condensation of the left lung as it sinks in water while the right swims, and it is heavier and feels more solid in the hand than the right.

The great Arteries.—Right innominate arises 7 inches from begin-

depends on that circumstance; they rather run longitudinally, and are thrown into a serpentine course, when the gut is shortened by the contraction of the longitudinal muscular fibres of the gut. The colon and rectum have very flat rugæ; these seem to depend on the contraction of the gut entirely." Of the arrangement in some other cetacea, Hunter says, in his *Observations* above referred to, 1787, p. 361:—"The intestinal canal of the *porpoise* has several longitudinal folds of the inner coat passing along it through the whole of its length. In the *bottle-nose* the inner coat, through nearly the whole track of the intestine, is thrown into large cells, and these again subdivided into smaller; the axis of which cells is not perpendicular to a transverse section of the intestine, but oblique, forming pouches with the mouth downwards, and acting almost like valves when anything is attempted to be passed in a contrary direction: they begin faintly in the duodenum, before it makes its quick turn, and terminate near the anus."

ning of aorta, left innominate after interval of $1\frac{1}{2}$ inches ; remains of ductus arteriosus attached at 5 inches beyond left innominate. Two large branches from aorta ; one half-way between left innominate and ductus, size of large injected human brachial artery ; the other opposite the ductus, from convexity of aorta, very large, fully size of injected human common carotid. In the parts removed with the heart there was only $1\frac{1}{2}$ inches of left innominate trunk. Each innominate gives off a branch, on deep aspect, $1\frac{1}{4}$ inches from origin ; right, size of goose-quill, left, size of crow-quill. *Right innominate* considerably larger than left (diameter, outside, $1\frac{1}{4}$ as against $\frac{1}{2}$ inch, thickness of wall about $\frac{1}{10}$ inch) ; length before division 3 inches ; its divisions, common carotid and subclavian, are of about equal diameter ($\frac{1}{2}$ inch). *Right subclavian* has remarkable *dilatation*, as capacious as hen's egg (length $2\frac{1}{2}$ inches) but shape of bent cone and somewhat flattened, the bulging on three sides, not on concavity. Where divided, just beyond dilatation, diameter of subclavian $\frac{7}{8}$ inch, interior, and wall only half the thickness of that of common carotid. Two branches, cut close to their origin, arise from the dilatation ; one from concavity, towards outer part of dilatation, size of human common carotid ; the other, crow-quill size, further on, from deep aspect.

Vagus and recurrent laryngeal nerves.—Left recurrent hooks round below ductus arteriosus, as in man ; is as large as human vagus in neck. Vagus is as large as human internal popliteal nerve. Right recurrent, as in man, hooks round below right subclavian.

Coronary arteries.—Left much larger than right. In preparing the heart I threw in spirit by the left coronary, and noticed that it did not return by the open pipe in the left. This seems to accord with the view maintained by Hyrtl that the coronary arteries do not anastomose, except, as he once remarked to me, by the capillaries ; here it would seem not even by the capillaries. Though I would not give this incidental observation as decisive, the trial was fair.

Food.—In the first stomach were found many bones of fish, apparently of small cod but I was not certain as to that ; many ear-bones of fish ; and many crystalline lenses of the eye. The food evidently had been fish. Whatever may be the kind of fish preferred by Beluga in its more northern habitat, salmon would seem to be a favourite when it strays to the Scottish coast. This one had pursued salmon into the net set for them ; the one the capture and skull of which (a female $12\frac{1}{2}$ feet long) is noticed by Sir William Flower (*Pro. Zoo. Soc.*, 1879, p. 667) was taken close to the salmon nets on the Sutherlandshire coast, caught by the tail between two posts ; and the Neill and Barclay one had been seen for three months swimming up and down in the upper reaches of the Firth of Forth, supposed to be in pursuit of salmon. The contents of the stomach are not mentioned by Barclay ; in Flower's case the contents were reported to him as "a few flakes of fish, which from size and colour might have been salmon." According to Van Beneden (*loc cit.*, 1889), the food of Beluga, besides fishes, consists "de Céphalopodes et de Crustacés, qu'il cherche au fond de la mer à des grandes profondeurs."

Tongue.—All that it would occur to me to call tongue is the first 6 inches; anterior 4 inches whitish and quite smooth; the next two inches a triangular area, apex backwards, with numerous small gland-openings, but no free papillæ anywhere and no circumvallate papillæ; the boundary of the triangular area presents fissures. The succeeding 5 inches of post-lingual region, until the white œsophagus begins, has numerous gland-openings, is soft and dark red, but firmer and white at the sides; and below the surface is a rete mirabile from which a very large amount of blood poured out.

TEETH.

The teeth of Beluga are interesting in their arrangement and adaptation, and from the worn conditions they present. Their number is variously given by authors.¹ The number in this beluga was, on each side, 10 upper, 9 lower.

Observation of the *alveoli* in skulls of Beluga shows well the

¹ *Lilljeborg* (op. cit., 1861-62, p. 243). "Teeth 10-9, 8-8, obtuse, and worn down."

Van Beneden and Gervais (op. cit., 1880, p. 535). "On en compte de 7 à 10 paires supérieures dans les crânes que nous avons sous les yeux; mais le nombre ne s'en répète pas toujours régulièrement à droite et à gauche; le plus généralement il existe 8 paires de dents inférieures. Les supérieures sont penchées en avant, les inférieures en arrière." In their reference, on the same page, to "Certains exemplaires possèdent une paire d'incisives supérieures," it is not clear whether they mean merely the anterior of ten upper teeth, or an incisor proper lodged in the transverse part of the intermaxillary, in the vestigial socket mentioned below in my remarks on the alveoli. In the latter meaning, the number of upper teeth would fall to be reckoned as 11. They finish with:—"Je trouve 9 germes de dents maxillaires, plus le germe d'une incisive à la mâchoire supérieure du fœtus du Béluga (Pl. xlii. fig. 1) et 9 germes de dents inférieures." Their artist has, in the figure referred to, probably by mistake, represented 11 or 12 in the upper and 11 in the lower.

Flower ("On the Characters and Divisions of the Family Delphinidæ," *Pro. Zoo. Soc.*, 1883, p. 505). "Teeth $\frac{3}{2}$ to $\frac{4}{2}$." In the beluga taken on the Sutherlandshire coast, in 1879, he found the number of the teeth to be, 20 upper, 16 lower. (*Pro. Zoo. Soc.*, 1879, p. 667.)

Van Beneden (*Bulletins de l'Académie royale de Belgique*, 1885, p. 27; and in vol. of Reprints, "Histoire Naturelle des Cétacés des mers d'Europe, par P. J. Van Beneden," 1889, p. 629). "Les dents varient de 7 à 10; ce sont les extrêmes; on en trouve le plus souvent de 8 à 10 de chaque côté et à chaque mâchoire." Further on (p. 631) he says—"Les dents sont communément de 8 à la mâchoire inférieure, de 9 on 10 à la mâchoire supérieure."

Amid these various statements there is want of definite evidence that the number in the lower jaw exceeds 9; or that in the upper jaw 10, unless there has been a rudimentary incisor. So it was in my beluga, 9 erupted lower teeth, no concealed tooth behind; 9 erupted upper teeth, with a concealed 10th behind; and, possibly, a vanished rudimentary incisor, lower as well as upper.

direction of the teeth, and affords more reliable evidence of the number of the teeth than by counting the number as seen in museum skeletons. It is easily seen that, besides a vestigial incisor socket above and below, the number in the upper jaw is 10, in the lower jaw 9.¹ The socket for the 10th upper, which was not erupted in my beluga, is very evident in the skulls. There is no socket behind the 9th lower, though a more than doubtful appearance in the skull of my beluga might hastily be taken for a 10th lower socket; the last lower socket is opposite the 8th upper socket. The *vestigial incisor socket* is plainly seen in the skull of my beluga. In the *lower* jaw, it is situated nearer the middle line than to the large succeeding socket; is about $\frac{1}{8}$ inch in diameter at the mouth (the right larger and more completely formed than the left); is over $\frac{1}{2}$ inch in depth, and directed straight forwards. The *upper*, situated at the middle of the intermaxillary bone (which is here only $\frac{1}{3}$ inch in breadth) where its palatal and marginal laminae meet, is about $\frac{1}{8}$ inch in diameter at the mouth (the right larger than the left), is over $\frac{1}{2}$ inch in depth, and directed straight forwards.

Form and wearing of the teeth in Beluga.—The teeth of Beluga have all originally a simple conical fang and a simple conical crown, but *as they appear in museums* the observer is apt to be misled unless he is aware that some, perhaps all, of what appear as the teeth, in macerated skulls, are but the stumps of teeth that had been excavated and broken off at the gum, or otherwise

¹ The sockets are very well seen in a skull of Beluga in the Edinburgh Museum of Science and Art, as all the teeth are out except a few on one side of the lower jaw. It is a larger skull than mine (length 24 inches, mine 21), taken at Cumberland Sound, Davis Straits, in 1861. Besides the vestigial incisor socket, the sockets are 10 upper, 9 lower. The vestigial incisor socket is as noticed in the text in my beluga skull, but the first large socket (the 10th from behind) is not placed as in mine entirely in the superior maxillary bone, but in between that bone and the intermaxillary bone, and so equally that it is difficult to assign it to one more than to the other, the apex at the suture. It is at the middle of the obliquely rounded-off anterior end of the jaw, over $\frac{1}{2}$ inch from the mesial line, while in mine the first large socket is placed farther out, where the rounding-off of the jaw begins.

The sockets of the *upper* jaw are all directed very obliquely forwards (to their orifice), increasingly so from the hinder socket forwards. They have also an outward direction, and from the socket proper a groove runs forwards and outwards on the bone, as if continuing the socket, for about an inch, thus giving further support to the tooth above. The anterior socket (that above noted as between the maxillary and intermaxillary) is small, only $\frac{1}{4}$ inch, but with groove

greatly worn down. Thus, in my beluga, as seen in the macerated skull, teeth that are noted below as broken off quite at the level of the gum, appear now as of considerable length beyond the alveoli.¹

Adaptations and wearing of the teeth as seen in this Beluga.—The following remarks and description of the form, arrangement, and wearing of the teeth of Beluga relate to this individual, as seen during the dissection and now in the macerated skull, in preparing which care was taken to secure that each tooth was placed in its own socket.

The teeth of Beluga may be said, generally, to be adapted for seizing fish and probably chopping them more or less before the swallowing. The three or four anterior pairs are more adapted for seizing, the posterior teeth more for chopping. The peculiarity of the teeth in Beluga is, that the upper and lower are not set directly against each other, nor so as to interlock

on the bone, which shows the direction to have been oblique forwards; 2nd to 6th are large, decreasing backwards; the four posterior decrease considerably backwards, the last (the 10th) $\frac{1}{4}$ inch across and nearly $\frac{1}{2}$ inch in depth.

In the *lower* jaw, the sockets are not nearly so oblique as in the upper. The three anterior are oblique, increasingly so from the 3rd to the 1st; the next two are nearly vertical, and those behind them are inclined backwards, the last three decidedly so. Nos. 1 to 7 are all large, No. 1 the largest; Nos. 8 and 9 are less, especially No. 9, but it is deeper than the two or three posterior in the upper jaw. The lower sockets are all deeper than the upper; the deepest of the upper (from the formed orifice) $\frac{3}{4}$ inch; the deepest of the lower, $1\frac{1}{2}$ inches. The lower teeth are thus more firmly socketed than the upper, and, except the three anterior, are given a more vertical direction in contrast with the forward and outward direction of all the upper teeth.

¹ I have to thank Sir William Turner for the opportunity of comparing the skull of my beluga with two beluga skulls in the Anatomical Museum of Edinburgh University, which through his exertions contains an extensive and interesting collection of skeletons and skulls and of other parts of the cetacea. In one of these beluga skulls, about the same size as my specimen, what appear as teeth are mostly but the stumps of teeth that had been excavated and broken at the gum. The other skull is considerably larger and the teeth much more robust, nearly twice as thick as in my specimen, some of the intervals between the stumps less than the thickness of the stumps themselves. In this specimen also, the crowns of the teeth are greatly worn. The large 2nd, 3rd, and 4th upper show marked excavation of what now remains of the crowns, behind and to their inner side; not as a special pit at the root, but obliquely along the remains of the crown, wearing it like a wedge, the thin free edge of which would either break or go on being worn down more and more. Most of the lower teeth are very bluntly and variously worn, except the 5th on the left side, which (like the 6th lower in my specimen) has no antagonist above, passing up between the 4th and 5th stumps, and has escaped wearing.

directly like the teeth in most of the toothed cetacea, but that, widely planted (the intervals wider than the thickness of the teeth) they meet their antagonists at an angle, and more or less decussate with them when the mouth is closed. This implies wearing of a peculiar kind. Farther, the upper teeth are all directed very obliquely forwards, and have also some obliquity outwards; while the lower teeth, except the three anterior, are nearly vertical and have little or no obliquity outwards. (See the diagram page 144.)

The result of that arrangement, stated generally, is that the point of the lower tooth wears its antagonist *behind and on the inside* and is itself worn *at the point*. Farther, as seen more distinctly on the large, more anterior, and more definitely set teeth, the lower tooth wears its antagonist at two places. In the movements of the mandible the lower tooth may strike the upper at the point and wear it to some extent there; but the place where it more definitely strikes, when the mouth is closing, is at what may be conveniently called its root, near the gum; wearing a pit in it there, which ultimately leads to the destruction of the upper tooth, by fracture taking place at or near the gum. The more posterior teeth, smaller and less definitely set against each other, also wear in that way or they may wear only at their points; and the lower may be the wearer of the point of either the tooth before it or of the tooth behind it in the upper jaw. The free movements of the mandible when the mouth is open, the front teeth not then interlocking, enables the lower tooth to wear the points of either of the two upper teeth between which it projects when the mouth is closing.¹

The natural *looseness of the teeth* is a farther source of

¹ Van Beneden and Gervais make the following general remark on the wearing of the teeth of Beluga, but without drawing the distinction between upper and lower teeth, or between anterior and posterior groups:—"la couronne est presque toujours entamée largement et d'une manière oblique, soit en dehors, soit en dedans, soit d'avant en arrière, plus rarement d'arrière en avant ou horizontalement." (*Op. cit.*, p. 535.)

The cause of the wearing in Beluga is different from that of the remarkable wearing seen in the walrus, in which the molar teeth of both jaws become worn obliquely on the inside to the level of the gum, their edges meeting externally. That can be caused only by champing against the shells of the shell-fish on which the walrus is said mainly to feed. But in Beluga, the wearing is by the friction of tooth against tooth.

uncertainty as to which of the two neighbouring teeth, among the posterior group, has effected the antero-posterior wearing at the points; but the lateral wearing at the points, is on the inside of the upper and on the outer side of the lower. I found the teeth all naturally loose, increasingly so backwards; that perhaps from the more posterior teeth being smaller, but the anterior pair were the loosest in both jaws, much more so than the 2nd or 3rd pair, the 1st in the upper jaw especially very movable. The lower teeth, generally, appeared to be quite as movable as the upper.

The study of the exact adaptation and wearing of each pair in relation to their antagonists in the other jaw, will be facilitated by first noticing the following:—In the natural condition, when the jaws were closed, the points of the teeth of the lower jaw, and on both sides, came exactly in contact, and at the same moment, with an opponent above; the point of contact being either at the pit the lower was wearing in the back of the crown of the upper, or at the end of the stump of the broken-off or very much worn down crown. When the teeth were thus in contact no lateral movement was allowed, only a little forward and backward movement, rubbing the teeth against each other. The natural motion seems to be simply up and down, by a snapping movement of the lower jaw. But when the mouth is somewhat opened the teeth may, by antero-posterior movement, be made to touch at their points, or, speaking generally, also to touch the point of the opponent behind.

The teeth thus correspond, tooth by tooth in the two jaws, on the five anterior pairs; but the 6th lower tooth has no antagonist above. Its conical crown passes up between the 5th and 6th upper and sinks into a soft smooth pit, $\frac{1}{10}$ to $\frac{1}{8}$ inch deep, in the gum of the upper jaw. This isolation of the 6th lower tooth dislocates numerically the relation of the three pairs of smaller teeth behind it, so that the three posterior teeth of the lower jaw, the 7th, 8th, and 9th, are opposed to the 6th, 7th, and 8th of the upper jaw; and the very short last-erupted tooth of the upper jaw, the 9th, has no possible antagonist in the lower jaw. (See the diagram page 144.)

The space above into which the unopposed 6th lower tooth passes is wider than those before and behind it, and the spaces below are narrower after the 4th tooth, but there is no particular crowding at this, as it were interposed 6th tooth. In the diagram the 6th lower tooth is represented as emerging too near the 5th. On surveying the whole series from the side, the change is seen to be accomplished gradually, and to be owing to the change in the point of emergence of the lower teeth in relation to the upper, implied in the change of direction of the lower teeth from the oblique to the vertical. Especially the two anterior of the three obliquely-directed lower teeth have to emerge behind the point of

emergence of their opponents above ; but when, at the 4th, the lower teeth change to the vertical direction, their point of emergence becomes anterior to that of their opponents, so that the 6th emerges opposite the interval between the 5th and 6th upper, and, being directed a little backwards and a little recurved, it naturally passes up unopposed, between the 5th and 6th upper, to its soft pit in the gum. The lower teeth are thus now, numerically, one in front of the upper, the 7th, 8th, and 9th lower opposed to the 6th, 7th, and 8th upper. From where the change in the relative position of emergence begins, the six posterior teeth of the lower jaw (4th to 9th) occupy exactly the same space of jaw ($3\frac{1}{2}$ inches) as the five teeth (4th to 8th) opposed to them in the upper jaw.

The teeth may be divided into an anterior group (five) and a posterior group (four), on the grounds of size and direction. The three anterior form a more definite group, from the oblique direction of the lower teeth here, but the 4th and 5th are also large. Of the $7\frac{1}{2}$ inches of upper jaw to the back of the 9th tooth, the anterior group occupy 5 ; of the $6\frac{1}{2}$ inches of lower jaw to the back of the 9th tooth, the anterior group occupy 4. The anterior group are in the narrower part of the jaw ; breadth of palate between the sockets, at first pair, $1\frac{1}{4}$ inches ; at third pair, $1\frac{3}{4}$; at fifth pair, $2\frac{1}{4}$; behind which the palate widens rapidly to 4 inches at the ninth pair.

(a) *Anterior group*.—The 1st is the least thick of the group. The three front *lower* are directed very obliquely forwards and also outwards, against back of upper ; the *upper*, more oblique forwards than lower except 1st pair, which are less oblique and more curved backwards like moderately bent hooks. *First pair*, the *left* wearing pit on back and to inner side of upper ; pit ovoid, $\frac{4}{12} \times \frac{2}{12}$ inch, reaching up to $\frac{1}{8}$ inch from gum, and goes half through thickness of crown. *Right upper* not worn at back ; upper and lower both more worn down at conical ends than left ; this wearing could be only when mouth a little open, enough to admit thumb. First pair well adapted for such act as seizing a fish ; both directed forwards and somewhat recurved, upper pair more recurved but projecting before lower ; when lower jaw advanced, lower pair just pass within upper, but no wearing seen on sides.

Second and third pairs, upper worn and broken off at gum, except right second. This is the longest tooth present, length of conical crown 1 inch, and $\frac{1}{2}$ inch of fang now exposed in skull. Is worn at the two places ; behind, at root of crown where shallow but well-marked vertically-ovoid pit seen, into which blunted apex of 2nd lower tooth fits ; and, above, worn behind at point, which can be done only by point of 2nd lower tooth advancing when mouth a little open. The worn and fractured ends of the left 2nd and of both right and left 3rd (and of both right and left 4th) upper teeth, have all the same appearances ; were seen in the dissection to be broken close to gum, now in skull $\frac{1}{2}$ to $\frac{3}{4}$ inch of fangs exposed. Each presents, on whole breadth of its end, an acetabulum-like cup, with narrow rough edge in front where excavated crown has at last broken off. Cup looks mainly downwards, but at fore part a little backwards,

where it is on broken remnant of crown. This direction of the cup mainly regulates direction of antero-posterior wearing of blunted points of opposing lower teeth; latter worn mainly in front until crown of upper is quite worn down, then bevelling of point of lower is mainly behind, fitting back part of cup. The worn adaptation is so perfect, the cups so smoothly worn and polished and so like each other, that they might be mistaken for the natural condition, reminding one of the cup of the ball and socket joint of the ophidian vertebræ. Crowns of lower are of good length, about $\frac{1}{2}$ inch, their bluntly conical ends work in and polish the cups, like pestle in mortar. Thus, while lower teeth suffer reduction only, by direct wearing at end, the upper have been ruined by the direction in which the lower are set against them.

Fourth and fifth pairs.—As 4th lower is nearly vertical, cup on stump of 4th upper is more oblique, its fore part being on small remnant of broken crown. Point of lower tooth is accordingly bevelled in front. 5th pair considerably less thick than 4th; not evident whether the great wearing down of crown of upper has been preceded by excavation and fracture. Lower 5th tooth has direction rather backwards, meeting, at least now, upper more directly; ends of both are bevelled in different direction from that of 4th and not symmetrically; on right side they meet abruptly, the bevelling in front on the upper, behind on the lower, being in opposite direction of bevelling of 4th; on left side, while the antero-posterior bevelling is in same direction as on right, there is also lateral bevelling, on inside of upper, outside of lower.

(b) *Posterior group.* The four posterior pairs (6th to 9th) are less thick than the anterior group, and diminish backwards as seen in the table. The lower are somewhat stouter teeth than the upper. The 6th lower, the unopposed tooth when mouth closed, shows, both right and left, some wearing on outside near point; that can have been effected only against side of upper 6th, in extreme backward movement of lower jaw when mouth not closed. Naturally, the 6th lower, directed a little backwards and a little recurved, passes up unopposed to its soft pit in the upper gum. The ruin of the 6th upper, seen on left side, has manifestly been effected by 7th lower tooth.

The following is the wearing seen on the three posterior pairs opposed to each other (7th, 8th, 9th lower, against 6th, 7th, 8th upper). Of the *upper*, on *left* side, 6th and 7th have been excavated behind and to inner side, and broken across at gum; the 8th, excavated, but the wedge-like remnant of the crown not yet broken off. On *right* side, no fracture, only the wedge-like wearing on inner and posterior aspect of reduced crowns of 7th and 8th, and a little on inside of 6th near tip. The three *lower* teeth (7th, 8th, 9th) opposed to the above three, inclined a little backwards, the 7th very little, show on all that remains of their crowns, wearing obliquely on outer side, wedge-like; the 7th less than 8th and 9th. These three posterior teeth are too narrow to show very definitely whether the antero-posterior wearing at the ends is in front or behind; but the bevelling of the upper appears to be mostly behind, that of the lower in front.

The 9th upper tooth has no antagonist below; there was an interval of $\frac{5}{8}$ inch between it and the 8th; when lower jaw is carried back to the extreme, it is still $\frac{1}{2}$ inch behind 9th lower. In macerated skull, it shows as if $\frac{1}{2}$ inch in length, but it projected only $\frac{1}{8}$ inch from the gum. Yet, that of right side shows a blunt end, as if worn obliquely on outside and forwards, but surface is convex; the left one, however, has conical end, only a little blunted, and shows the furrow, $\frac{1}{10}$ inch from apex, that marks off the original small terminal cone.

The 10th upper tooth, in the macerated skull appears $\frac{1}{2}$ inch in length, from mouth of socket, but it was entirely hidden in the gum, close below the surface; direction was very oblique forwards, more so than 9th; interval between 9th and it, $\frac{3}{8}$ inch. Right and left 10th have same form, the original terminal cone, $\frac{1}{10}$ inch in length, marked off by furrow where outer coating of the dentine ceases. On careful slicing into gum of lower jaw, no trace of a tooth corresponding to this 10th upper was seen; nor was any trace seen of a tooth opposite the 9th upper, but a 9th lower is already accounted for, placed opposite 8th upper.

Intermaxillary Region.—It may be here added that I sought with equal interest for a concealed tooth between the anterior pair of erupted teeth, in both jaws, but saw no trace of coming or former teeth. My search was down to the bone, but I cannot say whether I examined the contents of the vestigial sockets above referred to as now very evident in the macerated skull.

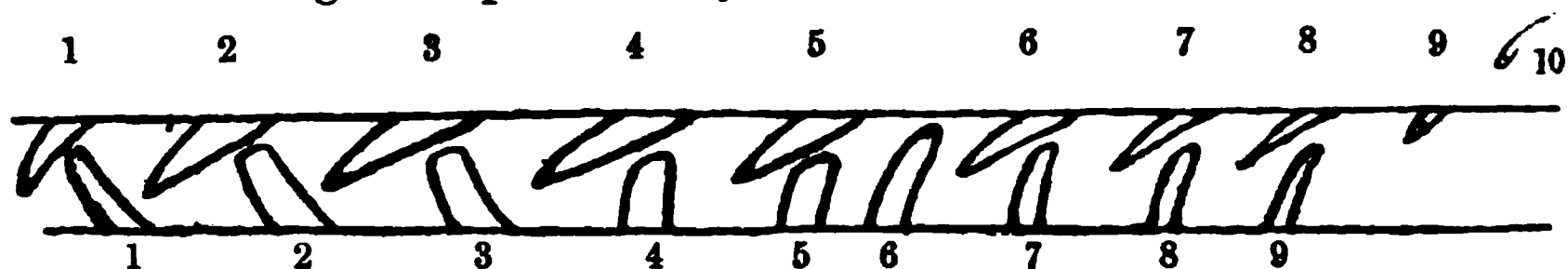
The following Table gives, in millimetres, the thickness of the

TEETH.	I	II	III	IV	V	VI	VII	VIII	IX	X
Upper, . .	5	8	8	7	6	5	4	3	3	2
Lower, . .	6	7	8	8	7	6	5	4	3	...
SPACES.										
Upper, . .	15	15	15	15	18	12	12	15	10	...
Lower, . .	15	12	12	10	10	8	10	10	...	...

several teeth in the upper and lower jaw, taken at the crown close to the gum, at right angles to the axis of the tooth; antero-posteriorly, in order to contrast with the width of the spaces. The teeth are nearly round, or a little oval antero-posteriorly; the latter form seen especially on the 2nd, 3rd, and 4th lower teeth. The spaces between the teeth are also given. They are taken at the same spot, horizontally. Each space, as numbered, is, it will be understood, behind the tooth of that number.

In reading this Table it has to be kept in mind that the 6th lower tooth has no opponent, but passes up to the gum in the 5th space; and that the opposing teeth behind it are, 7th lower against 6th upper; 8th lower against 7th upper; 9th lower against 8th upper; and that 9th upper has no opponent.

This diagram represents my view of what the crowns of the



teeth of this beluga were before they were worn, as far as I can judge from their present condition. It shows, as nearly as I could in a much reduced drawing, the relative thickness of the several teeth and the relative width of the spaces (except that the 6th lower tooth is represented as emerging too near the 5th). The point of each lower tooth is seen to be directed towards the part of the upper tooth which it excavates, near the gum, the surface of which is represented by the horizontal line. It might seem that the more anterior of the lower teeth should in like manner be worn by the point of the upper tooth behind, but the upper teeth pass outside the lower. It is seen that, at the 4th tooth, the lower begin to emerge on a line anterior to the upper, so that the 6th lower comes to emerge opposite the 5th space, into which it passes up to the soft pit in the gum, above noticed, and has no opponent. Behind the 6th lower tooth, the opposing teeth are, consequently, not numerically the same, being now 7th lower against 6th upper, 8th lower against 7th upper, 9th lower against 8th upper; and the very short 9th upper has no opponent. The tenth upper is shown as if concealed in the gum.

Thus, in this beluga, of the 8 *upper* opposed teeth, there are, on the *left* side, five (2nd, 3rd, 4th, 6th, and 7th) excavated and broken across at the gum; two (5th and 8th) greatly worn down, but the thin remnant of the crown not broken; and one (the 1st) has a pit dug in it near the gum, the farther wearing of which would have led on to fracture. On the *right* side two (3rd and 4th) are excavated and broken; three (5th, 7th, and 8th) are much worn down; on one (the 2nd) the excavation at the gum has begun; and only the remaining two (1st and 6th) have escaped with some wearing at the point. Of the total 16 upper opposed teeth, 12 are either broken or worn to the gum, and of the remaining four, two have the fatal pit being dug in them near the gum. The *lower* teeth are all more or less worn, but only at or near the points, their wearing being, so to speak,

the fair wearing of direct opposition. The upper teeth may also have more or less of that fair wearing at the points, in the various movements of the mandible when the mouth is not closed, but the wearing that proves fatal to them is that near the gum, the result of the teeth being so set that the point of the lower strikes against the back of the upper near the gum.

The meaning of this setting of the teeth in Beluga in relation to the œconomy of the individual and the maintenance of the species is not evident. The decussating direction of the upper and lower teeth may give a firmer hold on the prey that has been seized, but why not the same arrangement in other toothed cetaceans that have, as far as we know, much the same kind of prey to seize and chop, and have teeth that simply interlock? The looseness of the teeth may lessen the progress of the wearing, but it goes on as we see to the destruction of nearly all the upper-teeth before the animal is old. This beluga, as the state of the epiphyses of the vertebræ and humerus and forearm shows, was not old, only mature or nearly so. One cannot but think that this setting of the teeth in beluga must have some meaning of advantage to the animal in relation to its food, but the advantage would seem to be more than counteracted by the inevitably resulting destruction of the teeth. So great a loss of teeth must lessen the power of procuring food, and should thereby affect the longevity of the individual.

Temporo-maxillary articulation.—There was no synovial cavity either above or below; only fibrous tissue, about $\frac{1}{3}$ inch thick, between the two surfaces and uniting them; allowing of movement as free as compatible with that thickness of the uniting medium.

Abnormal last Rib.—The last rib was abnormal on the right side. A short rib, about 3 inches in length, was attached, like the two ribs in front of it, to the transverse process. At about 4 to 5 inches out, there was a rib in the flesh, about 9 inches in length, without, as far as we saw, any fibrous connection with the short piece.¹

¹ I could not ascertain at the dissection whether this loose piece was an additional 12th rib or serially a part of the 11th. My Museum Assistant at Aberdeen, Mr Robert Gibb, who has since articulated the skeleton, informs me that there are 11 ribs in all on each side, the undivided 11th rib on the left side is $14\frac{1}{2}$ inches in length.

(C) PECTORAL LIMB.

Form.—The pectoral limb is of great breadth in proportion to the length, as shown in figure 1. Length, from the junction with the body to the tip, along the middle, 16 inches; greatest breadth $10\frac{1}{4}$ inches. Figure 2 shows the framework by which the form is maintained. Anterior (radial) border very convex, maintained to its most prominent part by the pollex, and thereafter by the curvature of digit II, on to the somewhat blunt tip. The great breadth is obtained by the divergence of digits V and IV, especially of digit V, making the ulnar border still more convex than the anterior, but not evenly so, two projections being seen on it, the anterior opposite the end of digit V, the posterior opposite the end of digit IV. The greatest breadth is not at the anterior projection, but a little ($\frac{1}{2}$ inch) in front of the middle, owing to the great convexity of the radial border there. From the way in which the fin joins the body, the anterior border is longer than the posterior by 2 inches (18 against 16). Measured straight from the anterior and posterior parts of the junction to the tip, the anterior line is the longer by 3 inches (17 against 14).

In noting what was seen on dissection it will be convenient to begin with the bony framework.

When the paddle is removed at the shoulder joint, the length, from head of humerus to tip, is 19 inches. Of this the humerus forms 5 inches; the forearm, at the middle, $3\frac{1}{4}$ (radius 4); the carpus $2\frac{1}{4}$; the digital region, to the tip, $8\frac{1}{2}$.

Bones and Cartilages of the Digits.—The following particulars may be given in tabular form; the measurements in inches.

Digit.	Number of Bones including Metacarpal.	Length of Digit.	Length of terminal Car- tilage.	Distance of latter from edge of Paddle.
I	2	$2\frac{1}{2}$	$\frac{1}{2}$	...
II	6	8	$1\frac{1}{4}$	$\frac{1}{2}$
III	5	7	$\frac{3}{4}$	$\frac{3}{4}$
IV	4	5	$\frac{3}{4}$	$\frac{3}{4}$
V	3*	4	$\frac{3}{4}$	$\frac{1}{4}$

* In the other beluga noticed in the *Appendix*, digit V has a fourth ossification.

Figure 2 shows the digital bones, the intervening cartilaginous nodes with their intersecting joint, and the terminal cartilages.¹ All the digital bones are flattened; those of digit V less than in the other digits, except in the pollex, the phalanx of which is rounded. They have little of the hour-glass form so marked in the whalebone cetacea, and consequently the nodes project less.

Terminal cartilages.—The Table shows their length and how near they approach to the thin extreme edge of the paddle. That of digit I is conical, like the phalanx supporting it, the others are flattened, that of digit V not so much. That of digit II is long, narrow and tapering; those of digits III and IV at first broad, then tapering; that of digit V curved like the digit, broad at first, then tapering. On longitudinal section, there is no appearance of segmentation by a joint, except in that of digit V, the upper $\frac{1}{4}$ of which is cut off completely (seen on the surface as well as on section) by a joint, a diarthrodial flat-surfaced joint like those of the nodes, leaving a $\frac{3}{4}$ inch-long terminal cartilage beyond. Taken in connection with the presence of a fourth ossification there in the more advanced beluga, this is an interesting fact. So far as one instance can prove, it shows that segmentation precedes ossification, and supports the view that the number of elements in the digits is laid down originally.²

Carpus.—As I had previously found the carpus of Beluga of much interest in relation to the interpretation of the second row in the toothed cetacea I embraced the opportunity of again examining the arrangement carefully and give a full account of the several carpal cartilages and ossifications in this beluga, with my interpretation of them, but without entering on the

¹ This figure is taken from the other beluga noticed in the *Appendix*, as in the dissection of it enough of the skin was left at and towards the margin of the paddle to keep the digits in their natural position. The dissected paddle was pinned to a board and photographed, so that the figure shows all the parts in their natural relation. But they are the same, except that in this other beluga digit V has a fourth ossification, very small in the left paddle (the side figured), merely a rounded nodule about $\frac{1}{8}$ inch, about twice that size in the right paddle. Also metacarpal V is more fully ossified, and ossification generally in the limb is somewhat more advanced.

² The occurrence of segmentation in the terminal cartilages of the digits is noted and figured in my account of a 40 feet-long *Megaptera longimana* in this *Journal*, vol. xxii., 1888, p. 256.

wide field of comparing the arrangement with that in other toothed cetaceans.

Figure 3 shows these cartilages and the neighbouring parts, and the ossifications in five of the carpal cartilages as appearing on the surface. The four cartilages, including the small pisiform, shown as without ossification had none. The figure is reduced by photography from a full-sized drawing I made from the dissection. Reference to it will greatly facilitate in following the account of each of the cartilages. The measurements are given in inches, the breadths always before the lengths. The form and size of the cartilages are substantially the same on both surfaces of the carpus. The full extent of the ossifications is given as ascertained by the needle, as the marks made by the knife in excavating are apt to suggest fine lines of articulation and to obscure the true lines.

(a) *Pro-carpals*.—This carpus has the usual three bones or cartilages of the pro-carpal range of the cetacean and other mammalian carpus; in the nomenclature of Gegenbaur, the radiale, intermedium and ulnare; and a small pisiform. The ulnare and the pisiform are not ossified.

Radiale (fig. 3, *r.*): square-shaped (breadth $1\frac{1}{2}$, length $1\frac{1}{4}$); four articulations—proximally with less than half of radius; to ulnar side, largely with intermedium; distally, with two cartilages. Well ossified ($1\frac{7}{8} \times 1\frac{1}{2}$), especially to radial side.

Intermedium (fig. 3, *i.*):—the largest cartilage and ossification of the carpus and largely ossified ($2 \times 1\frac{3}{8}$, ossification $1\frac{3}{4} \times 1\frac{1}{8}$). Five articulations—proximally, mainly with radius and with about $\frac{1}{3}$ of end of ulna, pointed upper angle, but not sending a process up between radius and ulna, epiphyses of which meet each other above intermedium; to radial side, with radiale; to ulnar side, for shorter length with ulnare; distally, with three cartilages.

Ulnare (fig. 3, *u.*): a large somewhat triangular cartilage ($1\frac{1}{2} \times 1\frac{1}{8}$), not containing an ossification; six articulations—proximally, with greater part of end of ulna; to radial side, with intermedium; to ulnar side, with pisiform; distally, with one carpal and with two metacarpals, nearly the whole of M. V and about $\frac{1}{3}$ of M. IV.

Pisiform (fig. 3, *p.*): a small elliptical or ovoid cartilage set longitudinally (breadth $\frac{3}{8}$, length $\frac{5}{8}$); three articulations—from above downwards, with unossified part of epiphysis of ulna, with ulnare, and with metacarpal V. On free side, projects a little (about half its breadth) on ulnar line of carpus, so little that it is apt to be overlooked or injured in cleaning this border of the carpus.

It may be noted here, in connection with the little development of

the pisiform, that I saw no flexor carpi ulnaris muscle, generally present in the cetacean forearm and which I found present in the porpoise—(this *Journal*, vol. vi., 1871, p. 115) in which the other muscles of the forearm are represented by fibrous tissue. A fibrous band, about $\frac{1}{10}$ inch thick, adhering to the border of the ulna may possibly represent the degraded tendon of that muscle. The olecranon also is little developed, only a low knob projecting about $\frac{1}{3}$ inch, with a thin coating of cartilage.

(b) *Disto-carpals and Centrale*.—Here we see, as in other toothed cetaceans, less suppression of the typical five bones of the second carpal row than in the whalebone cetacea, among which we see the second row reduced to two bones in the fin-whales and to one bone or cartilage in *Mysticetus*. Here we have to determine the homology and consequent nomenclature of five bones. (1) The bone above the pollex, marked 1 in the figure, might be taken as the pollex metacarpal, and, in that case, the bone marked 2 in the figure as a stunted index metacarpal, lying alongside of the former and advanced beyond the level of the carpals; thus leaving those marked *c*, 3, and 4 as the only disto-carpals. Or (2) we might take 1, 2, 3, and 4 as disto-carpals and *c* as a centrale. Or (3) even admitting 2 to be a disto-carpal and *c* to be a centrale, it might still be held that 1 is the pollex metacarpal, resting on the radiale as metacarpal V rests on the ulnare.

On the whole, the second of these views is at least the most convenient interpretation and will determine the nomenclature adopted in the following notes of these cartilages, viz.—four disto-carpals, marked 1, 2, 3, and 4 in the figure (disto-carpal 5 suppressed), and a centrale *c*.¹ Nos. 1, 2, and 4 are well ossified; 3 and the centrale, like the much larger ulnare, contain no ossification.

¹ In regard to the third of these possible views, I would ask whether that discussion is not one merely of words? What makes a bone a carpal or a metacarpal, or what a pro-carpal or a disto-carpal? It is not form or ossification, but position or connection that determines our idea of the homology. It used to be held that the pollex metacarpal of man, from its mode of ossification, is a phalanx not a metacarpal, but that view is no longer tenable. Would it not, in regard to the carpus of some cetaceans, be quite as reasonable to consider that the suppression is pro-carpal rather than disto-carpal? And it is misleading to speak of a bone as “representing” two bones unless there is evidence, in the cartilaginous state or in early ossification, of there having been two distinct beginnings.

Disto-carpal 1: supporting the pollex; breadth and length about equal ($1\frac{1}{8}$); five articulations—proximally, with radiale; to ulnar side, with centrale and d.c. 2; distally, mainly with its metacarpal M. I, partly with angle of M. II. Well ossified ($1 \times \frac{7}{8}$).

Disto-carpal 2: placed transversely ($1\frac{1}{2} \times 1\frac{1}{8}$); five articulations—proximally, with centrale; to radial side, with d.c. 1; to ulnar side (but above rather than to the side) with d.c. 3; distally, with nearly whole of its metacarpal M. II, and with angle of M. III, with bone as well as cartilage of latter. Well ossified ($1\frac{1}{2} \times 1$).

Disto-carpal 3: a diamond-shaped cartilage, much smaller than d.c. 2 and 4, placed transversely ($1\frac{1}{8} \times \frac{5}{8}$); five articulations—proximally with intermedium; to ulnar side, with d.c. 4; to radial side, by blunted angle for about $\frac{1}{8}$ inch, with centrale, and (but below rather than laterally) with d.c. 2; distally with fully half of its metacarpal M. III, but with no other metacarpal. Contains no ossification (but has begun to ossify in the other beluga. See *Appendix*).

Disto-carpal 4: large ($1\frac{1}{2} \times 1\frac{1}{4}$), broadly diamond-shaped; five articulations—proximally, with intermedium and ulnare; to radial side, with d.c. 3; distally, with about half of M. III, and with about $\frac{2}{3}$ of its own metacarpal M. IV. Well ossified (1×1).

Centrale, c: a diamond-shaped cartilage (no ossification) closely resembling d.c. 3 ($1\frac{1}{8} \times \frac{5}{8}$), placed transversely, but with inclination upwards and outwards towards its articulation with radiale; five articulations, enclosing it between radiale and intermedium proximally and disto-carpals 1 and 2 distally, the fifth gained by touching the neighbouring angle of d.c. 3. It has exactly the same form and size on both surfaces of the carpus, it and d.c. 3 appearing as two diamond-shaped cartilages, touching each other for $\frac{1}{8}$ inch at their contiguous angles. (But not touching in the other Beluga, fig. 2.)

Relation of the Carpus to the Metacarpus.—Thus, the ulnare and all the disto-carpals except the reduced d.c. 3, support two metacarpals, by a major and a minor connection, the major with the metacarpal with which the carpal is serial. D.c. 3 supports only one metacarpal and but half of that, crushed aside, as it were, by the great size of d.c. 4.

Taking the carpo-metacarpal articulations from the metacarpal side, each metacarpal, except the diminutive pollex, rests on more than one carpal; M. II rests on two (its own carpal d.c. 2 largely, and on d.c. 1 small); M. III rests on three (its own carpal d.c. 3 and on d.c. 4 about equally, and on d.c. 2 less); M. IV rests on two (its own carpal d.c. 4 mostly, and on the ulnare for about a third); M. V rests on two (ulnare largely, and pisiform small). D.c. 1 and 2 alone appear to the eye as serial each with a metacarpal, and to them may be added the

ulnare, brought into relation with M. V by the absence of a d.c. 5. The serial dislocation at M. III is related to the small size of d.c. 3, encroached on by the large d.c. 4, the largeness of which appears to be related to its having to support two diverging digits. The less dislocation of the serial relation at M. IV, by the partial encroachment of the ulnare, appears to be related to the fitting of d.c. 4 into the nearly equal-sided socket formed for it between the two pro-carpals above.

Adaptations of the Carpus in relation to the Digits.—One tries to find the meaning of these carpal proportions and carpo-meta-carpal fittings in their adaptation to the digits, their length, robustness, and direction. A glance at the figures already given (in this *Journal*) of the carpus and digits in Megaptera (vol. xxii., 1888), in *B. musculus* and *B. rostrata*, and in *Mysticetus* (vol. xxix., 1895), will show that in the Finners the two great slightly curved middle digits are each, and they alone, provided with a disto-carpal, serving as cushions additional to the pro-carpus, to these two great digits; and that in *Mysticetus* the great solitary disto-carpal supports mainly the great middle digit.

Looking at the *direction* of the digits in Beluga, as shown in figure 2, we see the three outer beginning in line with the radius and general axis of the forearm, and curved so as to maintain the convexity of the radial border of the paddle: digits IV and V, beginning in line with the ulna, diverging from the others, digit V very divergent and curved in the opposite direction, digit IV widely separate from its neighbours, and not curved. Looking then to the relation of the digits to the carpus, as shown in figures 2 and 3, we see (a) the pollex, small and closely tied to its neighbour, resting on its carpal (d.c. 1) a stout bone for the support of so slender a digit but, with the radiale above, giving strength to the outer side of the carpus. (b) Digit II, the longest, rested on its large carpal (d.c. 2) and receiving support at its outer corner from d.c. 1, that latter support, and the obliquity of the joint, in adaptation to the direction of the digit. (c) Digit III, the most robust of the digits, rested in a socket formed by three carpals (its own carpal d.c. 3, and on either side d.c. 4 and 2). The oblique direction of the digit at its root seems to require a large d.c. 4 at the inner side of the triple socket, at the expense of d.c. 3 which is thus dwarfed. (d)

Digit IV, directed obliquely, is received into a socket formed by three cartilages (mainly its own carpal d.c. 4, the ulnare and the cartilaginous end of M. V). (e) Digit V, directed very obliquely, is also received into a triple socket (formed mainly by the ulnare, and on either side by the pisiform and the cartilage of M. IV).

Looking, further, at the adaptations of the *pro-carpals* to the disto-carpals and the digits, we see (a) The ulnare receiving directly the force of digit V and in part of digit IV, and transmitting it to the ulna. (b) The great intermedium standing opposite digits II and III, and receiving chiefly the force of these two digits and also in part that of digit IV, through the three intervening disto-carpals and the centrale, and transmitting it to the forearm, mainly to the radius as the greater bone of the forearm. (c) The radiale, standing opposite the pollex and part of digit II, transmitting their force to the radius, and forming a foundation for the thick outer border of the paddle. Of the interposed cushions formed by the disto-carpals, d.c. 4, with its great size, seems to play an important part, in relation below to supporting two diverging digits and above to transmitting their force to the ulnare and intermedium; and this may account for the dwarfing of d.c. 3, the "os magnum" of human anatomy. The centrale forms an additional cushion between digit II and the radiale and intermedium. The non-ossification of so large a cartilage as the ulnare is remarkable. The permanence of that condition will leave greater flexibility to the part of the paddle supported by digit V.

Joints of the limb.—The joints intersecting the *digital* nodes are diarthrodial and flat, allowing of some motion, but the bending effected is mainly by the flexibility of the cartilage of the nodes. Taking the digits as a whole, there is considerable flexibility, limited, however, by the ligament-like attachment of the representation of flexor and extensor tendons. The *carpal* and carpo-metacarpal joints are also diarthrodial, clearly so between the first and second rows and apparently also more or less at the lateral joints of both rows, but any bending at the carpus is owing to the flexibility of the general cartilaginous mass. The *wrist and elbow* joints are diarthrodial, but allow of extremely little movement. The great movements of the limb

are performed at the fully developed shoulder joint and by the movements of the scapula.¹

Fibrous-tissue representation of Finger-muscles.—Having noticed generally this interesting condition as seen in the Narwhal (this *Journal*, vol. vi., 1871, p. 115), and in *Globicephalus melas*, Phocena and Beluga (*ibid.*, vol. xxii., 1888, p. 268), I note it now more particularly as seen here. The above designation suggests the arrangement. The common tendon, or fibrous band, separates at the carpus, or both palmar and dorsal aspect, into five bands, one for each digit, having attachment to each phalanx and continued on to the last. At the metacarpus, here, these bands are $\frac{3}{4}$ inch broad and $\frac{1}{10}$ inch thick, being thereby bulkier than the extensor tendons of the human fingers. Traced up the forearm, the great fibrous band, or common tendon, on the extensor aspect, runs up at the middle, filling the interosseous hollow; on the flexor aspect rather as two more flattened bands one on each bone, on the whole less bulky here than on the extensor aspect but gaining strength on the carpus, metacarpus and phalanges, this especially marked on the divergent digit V.

In the cetacea that have finger-muscles the tendons are free, with slight exception at the carpus, till they reach the metacarpus or the first node, but here, in Beluga, the tendinous representation is attached in its whole course, and composed throughout of longitudinally-bundled white fibrous tissue. With that structure and these connections, it is manifest that these morphological representations of the flexor and extensor muscles can serve only the passive function of ligaments, giving resistance to overbending of the digits in the opposite direction.²

¹ The above presents some contrasts to the condition of the joints in whale-bone cetaceans (described in this *Journal*, Jan. 1895). Thus, in *Mysticetus* the joints distal to the elbow are not diarthrodial; either with only soft substance or, as at the carpus, fine fibrous tissue, between the cartilages. In the Finners, the digital joints are diarthrodial; those at the carpus and wrist not diarthrodial, the surfaces united by fine fibrous tissue; but in *Megaptera* there were synovial cavities above and below the disto-carpal that supports the greatest digit. The progress of the carpal joints to the diarthrodial condition appears to be related more to the number and ossification of the carpal elements than to the presence or size of finger muscles. Here, in Beluga, finger muscles are absent but the carpal joints are more or less synovial.

² The conversion of a muscle from the muscular to the purely ligamentous condition, whether from the embryonic state or in the course of the descent of species, requires only the disappearance of the more or less oblique muscular

APPENDIX.

Comparison of the Carpus with that of another Beluga.

I had only the pectoral fins of this beluga, taken in the Greenland seas in 1875. Although this was the first examined I have taken the 1884 one for description in the text, as belonging to the individual forming the subject of the paper, and mention here only certain differences in this one. But they are essentially similar, any differences depending mostly on the greater size and more advanced ossification. Figure 2 is taken from this beluga, and shows the different shape of the centrale in the carpus, but the figure is much more reduced than figure 2. This beluga was about a foot longer ($13\frac{1}{2}$ feet against close on $12\frac{1}{2}$, sex not stated). Paddle, from head of humerus 2 inches longer (21 against 19); the four larger digits about an inch longer; the pollex about $\frac{1}{2}$ inch longer; breadth of carpus 6 inches against 5 in the 1884 beluga, and consequently the carpal cartilages larger.

The same markings in detail are strikingly seen, *e.g.*, the same wide longitudinal groove on the palmar surface of the intermedium and d.c. 3, running from the interosseous space of the forearm; the same transverse depression on the palmar surface of M. II and III near their base, &c. The ulnare in this beluga also is entirely cartilaginous.

The following *differences* were found. (1) *Ossification* has begun in d.c. 3 in both wrists; a very small concealed ossicle placed rather to the radial side, in accordance perhaps with the greater relative size of that cartilage in this beluga (between the angles of the diamond, $1\frac{1}{4} \times 1$ inch on palmar, $1\frac{1}{2} \times 1$ on dorsal surface). Looked at from the side, the form might be described as rhomboid rather than as diamond-shaped. (2) The *centrale* is separated from d.c. 3 by an interval ($\frac{3}{4}$ inch on palmar surface, less on dorsum), allowing d.c. 3 to articulate so far with the intermedium, and the form is more rhomboidal, directed upwards and outwards to the radiale (length about $\frac{3}{4}$ inch, breadth $\frac{1}{2}$ inch). The form shown in figure 3 (of the 1884 beluga) would be changed to the form here by carrying the articulation with the intermedium rapidly down upon d.c. 2, thus cutting off the ulnar angle of the diamond. This difference in form may be recognised in figure 2.

The centrale has thus only four articulations in this beluga, shut in fibres, allowing the two aponeurotic expansions to coalesce, or the one aponeurotic expansion to adhere to the bone. Any muscle that has continuous fibrous tissue from end to end has, so far, a ligamentous function in addition to its contractile function. As remarked in my account of the finger muscles in *Mysticetus* (*this Journal*, vol. xii., 1878, p. 224), "In all these muscles the tendinous tissue is continuous from end to end, so that their ligamentous function is established. Were the muscular substance to disappear, the tendons and their prolongations would form ligaments, as we see in the entirely fibrous representatives of the finger muscles in the ordinary toothed whales."

between d.c. 2 and 3 distally and the radiale and intermedium proximally. On the dorsal surface it is more square-shaped, with the proportions changed, the upward and outward measurement $\frac{1}{2}$ inch, the upward and inward measurement about $\frac{3}{4}$ inch. The greater upward and outward extent on the palmar surface is owing to its there encroaching a little on the radiale.

The above applies to the left carpus. In the right carpus the centrale is somewhat different. On the palmar surface it is distinctly mapped out in the same situation as a shorter rhomboid ($\frac{1}{2}$ inch each way), but on the dorsum the exactly corresponding part is confluent below with d.c. 2. I may note that had the centrale not been visible as it is on the palmar surface, there is an appearance just above it that might have been taken for a vanishing centrale, in the seeming marking off of the lower corner of the intermedium here by a transverse weakness in the cartilage, and on the dorsum by one of several rough grooves, but they are not of the articular kind. I note this as a caution to those who may be too easily satisfied in their search for a centrale. Several of the carpal bones in this beluga show roughnesses on the surfaces as if from more than normal action.

EXPLANATION OF PLATE IV.

Fig. 1 shows the form of this beluga, from a photograph, reduced to about $\frac{1}{20}$; pectoral fin and tail-fin seen in full view, not as seen in the photograph. Along *dorsal* line, are seen, above the beak, the forehead cushion; behind this the elevation at the blow-holes, forming top of head; between forehead cushion and blow-hole eminence, a concavity; behind blow-hole elevation, the cervical concavity; on body, the general convexity of back, becoming concave towards caudal part of body. No special elevation indicating a rudimentary dorsal fin. On *ventral* line, general convexity back to depression at anus; behind that, caudal region convex, more so as it turns up to tail-fin. *Tail-fin*, turned round so as to show full length and breadth, depth of median notch and form of lateral lobes. *Pectoral fin*, shown in full breadth, very broad form seen; behind its blunt point, two projections seen corresponding to digits IV and V; great convexity of ulnar border behind that, and of entire radial border, shown, more fully seen in fig. 2. Position of ear-hole seen as small dot some way behind eye.

Fig. 2. Left pectoral limb, palmar surface, from another and larger beluga; direct from photograph of the dissection, reduced to about $\frac{1}{7}$. As the bones of the digits were still supported by skin on dorsal surface, the fig. shows exact position of each digit. See great divergence of digit V, digit II going to point of paddle, and digits IV and V forming the two projections, seen also in fig. 1. Distal epiphysis of radius and ulna shown as cartilage, but ossified within.

Small size of olecranon and pisiform seen. *Carpus*.—See lettering on fig. 3. Same arrangement as in carpus of fig. 3, but centrale does not articulate with disto-carpal 3. Metacarpal IV seen in this beluga to articulate with carpal cartilage of metacarpal III. Carpal ossifications seen as they show on the surface. Disto-carpal 3, in this beluga, contained small ossification, not seen. *Digits*.—Diarthrodial joint indicated intersecting each node. Number of bones, including metacarpal, in each digit; pollex 2; index 6; medius 5; annularis 4; minimus 4, the fourth a very small ossification, not present in beluga from which figs. 1 and 3 are taken. Terminal cartilages of digits seen, of digit II, long and tapering; the others broad at first then tapering; their distance from edge of paddle seen.

Fig. 3. Left carpus, &c., palmar aspect, photograph from full-sized drawing from nature by author, reduced to $\frac{1}{3}$. Bones shown in outline only, cartilages of carpus dotted dark, other cartilages dotted lightly. *R* and *U*, lower ends of radius and ulna; cartilage of epiphyses seen, conceal ossified epiphyses which are united to shaft; epiphyses at elbow and shoulder also united to shafts. *Carpus*, lines of articulation bounding each cartilage seen. Procarpals, *r*, radiale, with its ossification; *i*, intermedium with its ossification, seen not to pass up between radius and ulna; *u*, ulnare, not ossifying; *p*, pisiform, very small, not ossifying. Disto-carpals, *1*, carpale I, with its ossification; *2*, carpale II, with its ossification, seen to project distally more than the other disto-carpals; *3*, carpale III, small and diamond-shaped, not ossifying in this carpus, but ossifying in carpus of fig. 2; *4*, carpale IV, with its ossification (carpale V suppressed); *c*, centrale, seen to articulate also with disto-carpal 3, but not in fig. 2; *I*, metacarpal of pollex, entire pollex shown, one phalanx and terminal cartilage; *II*, *III*, *IV*, and *V*, metacarpals of these digits with cartilaginous epiphysis at each end. Metacarpal V seen to be incompletely ossified; metacarpal II with peculiar proximal end. The exact articulations of each carpal cartilage are shown. Metacarpal IV in this beluga does not articulate with metacarpal III, separated by lower angle of disto-carpal 4. The ossifications of the carpals are shown as they appear on the surface.

THE MORPHOLOGY OF THE TRUE "LIMBIC LOBE"
CORPUS CALLOSUM, SEPTUM PELLUCIDUM AND
FORNIX.¹ A preliminary communication by G. ELLIOT
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of Sydney, N.S.W.*

IN this research over seventy brains of non-placental mammals, adult and foetal, have been examined by means of dissections, and serial sections in various planes. Various methods of staining have been used. The bulk of the work has been done with the method of Weigert and its various modifications. The Golgi method has also been employed in many cases. For comparison a large number of Eutherian cerebra have been examined, special dissections having been made of the brains of the rabbit, pig, dog, guinea-pig, sheep, rat, and man. Foetal brains of the pig, rat, and man have been examined. A number of brains of birds and several reptilian brains (tortoise, lizard, and snake) have also been examined. For much valuable material I am deeply indebted to the generosity of Professors Wilson and Anderson Stuart, and Mr J. P. Hill.

In 1838 Gerdy described, under the name "*circonvolution annulaire*," a marginal band of the mesial hemisphere wall surrounding the "hilum" (*grande ouverture de l'hémisphère* of Foville and Gratiolet). He included in this band the region now known as the gyrus fornicatus, which he described as being connected anteriorly with the olfactory lobe, and posteriorly with the gyrus hippocampi. He regarded the ring as being interrupted by the vallecule Sylvii.

In the following year Foville, from a study of the human brain, added the locus perforatus anticus of Vicq-d'Azyr and the external

¹ The subject-matter, of which this paper is a synopsis, formed part of a Thesis, dealing with the Comparative Anatomy, Histology, and Embryology of the cerebrum of the Monotremata and Marsupialia, which was awarded the University medal by the examiners for the degree of Doctor of Medicine of the University of Sydney in March 1895.

[This Memoir, dated Sydney, August 2, 1895, was received September 14th.—
EDITOR.]

olfactory root to complete the bordering ring of Gerdy, and called the complete marginal bond the *circonvolution de l'ourlet*.

In 1877 Broca, after studying the comparative anatomy of the cerebrum in a series of mammals, revived the idea which Foville had advanced from human anatomy, and on morphological grounds separated the callosal and hippocampal convolutions with the olfactory lobe from the rest of the hemisphere. Since these parts appeared to him to immediately bound the threshold (*seuil-limen*), he distinguished them as the *limbe de l'hémisphère* (limbus) or the *grande lobe limbique*.¹

To Broca's lobe in 1881 Schwalbe very properly added² the fascia dentata, septum pellucidum and fornix, and, excluding the olfactory bulb, called the reconstructed lobe *falciform*. The subsequent researches of Zuckerkandl have shown that a number of rudimentary convolutions in the Eutherian brain—including the *gyri supracallosus*, *geniculi subcallosus* and *infracallosus*, the *induseum griseum* of Obersteiner and the *striæ longitudinales Lancisi*—must be added.

Anatomists generally have recognised the lobe in its modified form, and it has unfortunately been introduced into text-books as a "lobe" of the brain.

In commencing the study of the non-placental mammalian cerebrum last year I was at once met by the difficulty that it was quite impossible to describe the cerebrum in question according to the accepted method of subdividing the brain. In other words, the limbic or falciform lobe of Broca and Schwalbe was found to be quite incompatible with the brain of the Proto- and Meta-theria.

On studying the subject in relation to the developing Eutherian brain, I found that the same objections to the acceptance of Broca's theory also obtained there as in the marsupial.

As the morphology of the region is so largely influenced by the development of the corpus callosum and septum pellucidum, it will be necessary, for the sake of clearness and completeness, to briefly examine the main factors in the evolution of these structures.

In the cerebrum of all non-placental mammals the "hilum" of the hemisphere is completely surrounded by a distinct and well-defined ring of grey matter, whose several parts present quite as high a degree of histological differentiation as is found in any Eutherian brain, so that their recognition is certain and easy. This marginal band, moreover, is the only part of the hemisphere which is intimately associated with the olfactory apparatus. Hence, as it fulfils the two conditions which Broca believed to characterise his limbic lobe, *i.e.*, that it is "limbic"

¹ *Bull. de la Soc. d'Anthropologie*, 1877, t. xii. p. 646-657.

² *Lehrbuch der Neurologie*, 1881.

and olfactory, this region may be distinguished as the "true limbic lobe." This region, moreover, is phylogenetically the most ancient part of the cortex cerebri, which, as will be explained later, is the reason why it is marginal.

In the cerebrum of *Ornithorhynchus* (fig. 1) this bordering ring consists of three histologically distinct parts; and as their general topographical relations resemble those of the Sauropsidan

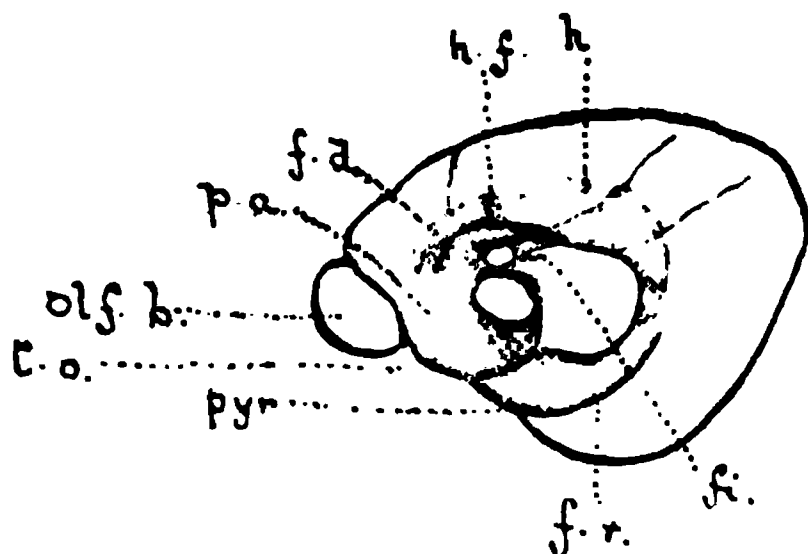


FIG. 1.—Mesial surface of cerebrum of *ornithorhynchus*.—*f.d.*, fascia dentata; *fi.*, fimbria; *f.r.*, rhinal fissure; *h.*, hippocampus; *h.f.*, hippocampus fissure; *olf.b.*, olfactory bulb; *p.a.*, præcommissural area; *pyr*, pyriform lobe; *t.o.*, tuberculum olfactorium.

and higher Ichthyopsidan brain, their mode of arrangement may be accepted as a general type for the whole vertebrate series.

The true limbic lobe in its primitive form consists of three parts, which may be distinguished as the dorsal and ventral limbs and a "pars intermedia." The *dorsal limb* (fig. 1, *h*) is formed by the hippocampus, which not only forms the upper margin of the fissura choroidea in its whole length, but extends forwards as far as the anterior extremity of the cerebrum. The *ventral limb* (*pyr*) is formed by the pyriform lobe, which forms the inferior lip of the "porta,"¹ and bends upwards behind the hilum to become continuous with, and overlap, the caudal extremity of the dorsal limb. The *pars intermedia* consists of an extensive grey mass, which forms the anterior boundary of the "porta" of the hemisphere, and connects the anterior extremity of the *dorsal limb*, which lies above it, with the anterior extremity of the *ventral limb*, which lies below it, thus completing the marginal ring. It consists of three parts—(1)

¹ The term "*porta*" is not used here with any strict anatomical significance as Wilder uses it, but merely as a convenient term with a self-evident significance.

the "*precommissural area*" of the median cortex, (2) the thickened lamina terminalis which is the homologue of the septum pellucidum of higher mammals, and (3) the tuberculum olfactorium.

In the mammalian group the simplicity of the arrangement of this early limbic lobe becomes considerably obscured, and its morphology greatly disturbed by three main factors:—(1) by the bending down of the posterior extremity of the hemisphere to form a descending horn, (2) by the growing pallium overlapping and otherwise obscuring parts of the marginal ring, and (3) by the development of the corpus callosum. These three modifying elements are more or less directly the result of the rapid growth and the large proportions of the pallium (Turner)—which is *the* great characteristic feature of the mammalian brain. Although these three factors are merely different expressions of the one great cause, their several effects are so distinct from one another, that it is convenient to discuss their influence upon the marginal region separately. The development of the commissures has such an important bearing upon the questions under consideration that a short account of their phylogeny is necessary to elucidate this subject. This account, however, is little more than a synopsis of this part of the subject, which will be discussed more fully in a subsequent paper.

Caudal flexion of the hemisphere.

Late in the foetal life of the lowest mammal, the posterior extremity of the cerebral hemisphere becomes bent downwards to form a small descending horn. The posterior extremities of the hippocampus, choroid fissure and pyriform lobe, which form part of this caudal pole of the hemisphere (and which hitherto had been practically horizontal), now, of course, become correspondingly flexed. The result of this bending upon the posterior extremity of the hippocampus in *Ornithorhynchus* is shown in figures 1 and 2. In *Echidna* (fig. 3) the bend becomes more marked, so that the hippocampus, instead of being entirely *dorsal* to the "hilum," now forms the whole of its *upper and posterior* margins. As the result of the flexion of the pyriform lobe, its posterior part becomes bulged downwards, giving rise to

a natiform or "hippocampal" eminence, which in *Platypus* is practically absent, owing to the slight degree of flexion.

In the marsupial the bending of the hemisphere goes a stage further than in *Echidna*, so that the hippocampus and choroid fissure (fig. 4) form regularly arched structures, which not only bound the hilum above and behind, but also *partly below*. The exact amount of bending varies in different marsupials and placental mammals (fig. 5), but it is always greater than in *Echidna*. Thus in Man the bend is so extensive that the recurved tip of the hippocampus almost touches the locus perforatus anticus.

The pyriform lobe.

In all mammals above the monotremes the pyriform lobe, as a result of the caudal flexion of the hemisphere, becomes divided into two parts by a deep depression or notch, which constitutes the *vallecula Sylvi* (Turner). The part of the lobe which lies behind this depression becomes very prominent (mainly as a result of the bending) and constitutes the *eminentia natiformis* (hippocampal lobule, gyrus hippocampi seu uncinatus). To this region the name "pyriform lobe" is also very generally restricted. The inaccuracy of such a nomenclature is clearly demonstrated in the brain of *Platypus*, and to a less degree in that of *Echidna*.

Beginning immediately behind the bulbus olfactorii upon the basal aspect of the cerebrum of *Ornithorhynchus*, and extending backwards on to the mesial aspect (fig. 1, *pyr*) to terminate behind the "tail" of the hippocampus, there is a fairly uniform strip of cortex of a pale grey colour, which is cut off from the adjacent regions by two deep and well-defined fissures. In the whole of its extent, from the place where it becomes continuous with the pedunculus olfactorii to its termination in relation to the hippocampus, it presents a uniform histological structure. Examined by the methods of Golgi and Weigert it presents a uniform (in transverse section) superficial layer of medullated nerve fibres, which, after giving off a number of fine "collaterals," themselves terminate by end-branchings in relation to the protoplasmic processes of the cells of the region. The pyriform

lobe contains a large number of scattered small polymorphous cells, but in addition presents a very regular row of medium-sized cells, which closely resemble those which v. Koelliker has described under the name "Doppelpyramiden" in the Rabbit as being characteristic of the pyriform lobe. There is therefore no reason to restrict the term "pyriform" to the caudal extremity, and exclude all the remainder of the same histological formation.



FIG. 2.



FIG. 3.



FIG. 4.

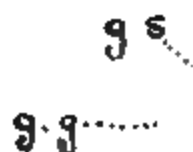


FIG. 5.

In the whole of its extent the pyriform lobe is bounded laterally by a deep rhinal (ectorhinal—Turner) fissure, which posteriorly extends on to the mesial hemisphere wall (fig 1, *f.r.*). The anterior extremity of the pyriform is separated from the tuberculum olfactorium, which lies on its mesial side, by a well-defined fissure—the *endorhinal* of Turner. In both monotremes the fibres of the "external olfactory radiation" (Edinger) as

they proceed backwards are uniformly scattered over the surface of the pyriform lobe, but in all the marsupials and in most placental mammals the fibres become collected to form a well-marked strand lying in the fissura endorhinalis. For this reason Herrick distinguishes the latter as "*fissura radialis*." The fissura endorhinalis appears much earlier in development than the f. ectorhinalis, because the tuberculum olfactorium develops very early. The fissura ectorhinalis first appears in the mammalia; and while the proportion of pallium to rhinencephalon is inconsiderable, the fissure is apt to be indistinct, or even absent. Thus in *Perameles* there is hardly any fissure at all, and in *Notoryctes* it appears to be quite wanting. The pyriform lobe corresponding to its early appearance in phylogeny reaches the height of its development early in ontogeny. As the pallium increases there must soon come a time in most mammals when the growing pallium must "bulge over" as it were, the relatively stationary pyriform producing the endorhinal fissure.

Platypus, from its aquatic habits, has a small (relatively) olfactory apparatus, and therefore a small pyriform lobe, which lies entirely upon the basal and median aspects of the cerebrum. But in animals with a largely developed olfactory apparatus and a small pallium (*Notoryctes*, *Perameles*, *Dasyurus*) the pyriform extends well on to the lateral aspect of the cerebrum, or even forms the greater part of that surface. In macrosmatic animals with a large pallium (*Echidna*, *Macropus*, *Hypsiprymnus*), as also in animals who have much smaller pallia but are also *relatively* microsmatic (*Ornithorhynchus*, *Phalangista*, *Petaurus*, *Phascogale*), the pyriform is mainly basal.¹

The application of the name "*hippocampal*" to part of the pyriform, from a supposed essential connection between the two regions is very unfortunate, and has been the cause of extreme confusion among certain writers upon this region. In Man, and in many other microsmatic mammals, the anterior part of the pyriform lobe (corresponding to the vallecule Sylvii and the outer border of the locus perforatus anticus) becomes more affected by the general atrophic process which involves the

¹ All monotremes and marsupials are macrosmatic. The statement of Symington that *Ornithorhynchus* and of Wiedersheim that the monotremes are microsmatic is very misleading.

whole olfactory apparatus, than the posterior part (gyrus uncinatus). In all placental mammals (as will be explained later) only the caudal extremity of the Metatherian hippocampus is represented. Hence, in the higher mammals only those parts of the hippocampus and pyriform are left which are topographically related to one another. Hence anatomists have inferred that the relation was essential and applied the name "hippocampal" to this part of the pyriform. It has been further assumed that the subiculum cornu ammonis, forming as it does in man part of the gyrus hippocampi, belongs to the pyriform lobe. An examination of the cerebrum of any non-placental mammal, and especially Platypus, at once removes all doubt upon these points. In the first place, the hippocampus and pyriform lobe are only topographically related at their caudal extremities (fig. 1). It would be wise, therefore, to discard altogether the term "hippocampal" as applied to part of the pyriform lobe. In the second place, the subiculum cornu ammonis is coextensive with, and forms part of, the hippocampus. It therefore does not belong to the pyriform lobe or gyrus uncinatus.

Alexander Hill,¹ largely as the result of an investigation upon a brain of *Ornithorhynchus*, but evidently not thoroughly well preserved, has made a laudable attempt to clear away the confusion in nomenclature which the investigator meets on every side in the study of this region. The condition of the specimen was obviously such as to make it difficult for the author to recognise important connections in the very region whose nomenclature he wished to reform. As a consequence, the confused state of the nomenclature of this region has not been cleared up. Without any explanation he restricts the term "rhinencephalon" to the pyriform lobe,² thus giving a new and quite uncalled-for significance to a term which has already quite a perplexing variety of meanings. This term has to-day a definite and exact significance, which Sir William Turner suggested, and adopted in his system of cerebral nomenclature.³

¹ *Philosophical Trans.*, vol. 184, p. 367, and p. 395, e.s., 1894.

² [On p. 367 the rhinencephalon is defined, as stated in the text, as the pyriform lobe, but on p. 375 Dr Hill says that the hippocampus forms, as was recognised by Broca and Zuckerkandl, a part of the rhinencephalon.—EDITOR.]

³ *Journal of Anatomy and Physiology*, vol. xxv., October 1890.

Turner's rhinencephalon corresponds to the "limbic lobe" of this paper, with the olfactory bulb, and, as such, is a perfectly rational and very convenient division of the brain, both to the descriptive anatomist and the morphologist. This term has been used with a variety of meanings. Thus Geoffrey St Hilaire and Robin applied it to unioocular monsters. Owen used it as synonymous with *bulbus olfactorii*. Wilder has suggested that it be used in much the same sense as the Germans use the term "*lobus olfactorii*," and Schäfer (*Quain's Anatomy*) would use the term in the same sense as the term limbic or falciform lobe is generally understood. If this term is to be used at all, it should be employed with the meaning that Turner has attached to it.

In addition to this, Hill's suggestions concerning the fascia dentata and olfactory apparatus generally, resting as they do upon very doubtful and (as he himself admits) incomplete data, were at the time they were made obviously premature, and, as subsequent research has clearly shown, quite opposed to fact.

He would have us believe that the morphologically posterior pole (temporal) of the pyriform is the anterior extremity; that the fascia dentata, which is clearly the edge of the cortex, is neither cortical nor the margin of the cortex; and that the fascia dentata, which he has shown to be part of the smell centre, is quite disconnected with the olfactory apparatus, except possibly through the medium of the thalamencephalon.

The Hippocampus.

In a foetal *Ornithorhynchus* of 8 cm. the whole of the mesial hemisphere wall above the fissura choroidea is hippocampus. In front of the region of the foramen of Monro (where, of course, the fissura choroidea ceases), the hippocampal formation is continued forwards in the same relative position as far as the extreme anterior end of the hemisphere. The dorsal lip of the fissura choroidea is formed by the most ventral part of the hippocampus, which is the rudimentary fascia dentata. This is continuous above with the rudimentary cornu Ammonis, which forms a shallow trough (Bogenfurche). The supero-mesial

border of the hemisphere corresponds to the subiculum cornu Ammonis. In front of the foramen of Monro the fascia dentata becomes directly continuous with the "precommissural area."

In Sauropsida the hippocampus lies in the corresponding position upon the mesial hemisphere wall. It does not, however, stop at the supero-mesial angle, but extends on to the dorsal aspect of the hemisphere. Although the fascia dentata still lies wholly upon the mesial surface of the hemisphere, the cornu Ammonis partly and the subiculum cornu Ammonis wholly lie upon the dorsal aspect. In the Amphibia the representative of the fascia dentata probably extends on to the dorsum of the hemisphere.

In the mammalian brain the appearance and subsequent rapid growth of a pallium relegates the hippocampus to the mesial wall, of whose surface it forms a gradually lessening part as the animal scale is ascended. In its growth the pallium tends to encroach upon the hippocampus from above, at the same time that the fascia dentata is extending upwards from below. As a result of these two factors the hippocampal formation becomes inrolled and folded in a manner, which is so characteristic of the mammalian brain. In Platypus the folding and the histological differentiation of this region are as complicated as they are in Man. Corresponding to its early perfection phylogenetically, its growth in the mammalian foetus is also precocious, so that it is fully developed at a time when the pallium is rapidly extending. Its morphology is "*fixed*," therefore, at a time when the actively growing and plastic pallium is still extending. It is not accurate, therefore, to say, as Giacomini has done, that this region does not behave like a convolution, simply because its morphology is constant in the whole mammalian series. It is constant simply because, with the early development of the smell-apparatus, this part of the smell-centre also develops early, and is therefore not subject to influences which affect other cortical regions later. It must not be forgotten, however, that in the production of the complicated inrolling, the pallium takes an active part. In the Sauropsida, where this factor is wanting, the inrolling is also wanting. In *Notoryctes typhlops*, where the pallium is probably smaller than

in any other mammal, the hippocampus is markedly simpler than it is in *Perameles nasuta*, an animal only a little higher in the scale of pallial development.

In *Notoryctes* almost the whole width of the *fascia dentata* shares in the constitution of the mesial hemisphere wall. In *Perameles* only part of the *fascia dentata* lies upon the surface. As the pallium extends it gradually overlaps the hippocampal region, beginning at its posterior extremity, until in the highest Marsupials the hippocampal region is completely shut out from the mesial hemisphere wall by a pallial operculum. This condition is met with in *Macropus*, *Petrogale*, and *Hypsiprymnus*, and there is a complete gradation up to this stage, beginning with *Notoryctes* and *Perameles*, *Dasyurus*, *Phascolarctos*, *Petaurus*, and *Phalangista*. Both monotremes occupy an intermediate position between the two extremes, resembling *Dasyurus* more than any other marsupial. Thus a small region of *fascia dentata* (fig. 1, *f.d*) is exposed as a fusiform grey mass immediately above the fornix commissure and fimbria (*fi*). Apart from this, the anterior extremity of the hippocampus in the Proto- and Meta-theria affords a striking example of the influence of the pallium upon the morphology of the hippocampus. It has already been mentioned that the hippocampus extends forwards in the foetal Platypus on the dorsal aspect of the precommissural area. As the pallium grows and tends to encroach upon the hippocampus in this region, the latter gives way and bends down in front (fig. 1), invading (as it were) the precommissural area (*p.a*). This anterior extremity of the hippocampus does not become folded like the rest of the hippocampus, which cannot recede before the pallium, but retains a simplicity of form which recalls the structure of the reptilian hippocampus.

The caudal flexion of the hemisphere naturally has a marked effect upon the "tail" of the hippocampus; but before this can be discussed fully, the commissures must be described.

(To be completed in next Number.)

ANOMALOUS MUSCLE OF THE THORAX, CONNECTED
WITH THE DIAPHRAGM. By FRANCIS J. SHEPHERD,
M.D., *Professor of Anatomy in M'Gill University, Montreal.*

IN a well developed male subject which was dissected during last winter was found the following muscle :—

On removing the left lung and parietal pleura, a long flat ribbon-shaped muscle was seen running down the left side of the bodies of the dorsal vertebræ ; it arose from the anterior surface of the head of the sixth and seventh ribs, near the vertebral articulation, by a fleshy origin half a centimetre wide. As the muscle descended it became broader, until it reached a width of two and one-half centimetres. It ended in two slips, the most posterior becoming tendinous, and then again muscular, blended finally with the lesser arcuate ligament of the left side ; the anterior slip, which was muscular to its termination, but had a tendinous intersection, was continued with the left crus of the diaphragm, becoming blended with it.

Anomalous muscles connected with the diaphragm are rare, and I have been unable to discover a case similar to the one above described. The significance of this muscle I am at a loss to determine. Might it not be a remnant of what Prof. Sir Geo. Humphry calls the *sub-vertebral rectus* which is found in the Japanese salamander, of which the crura of the diaphragm forms the lumbar remnant in mammals?

Fig. 1.

a.n.

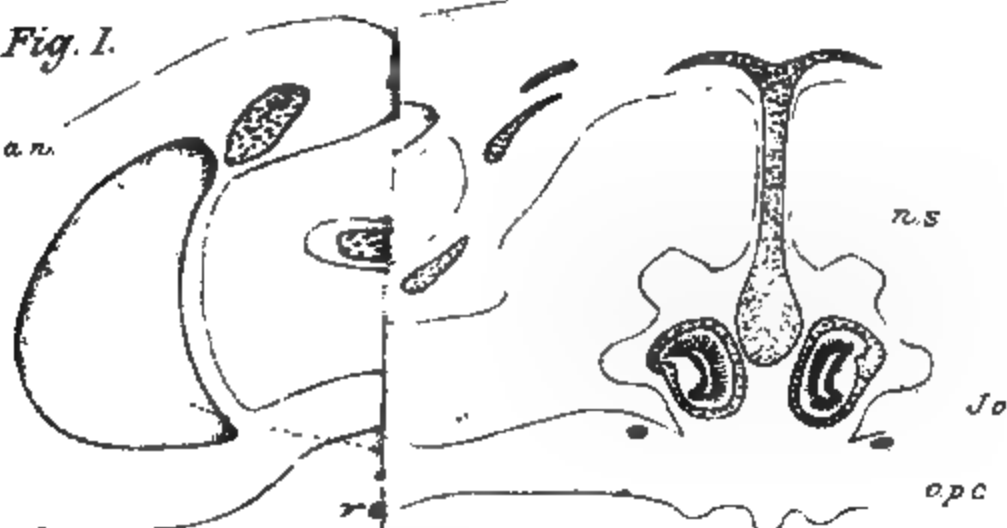


Fig. 2.

a.n.

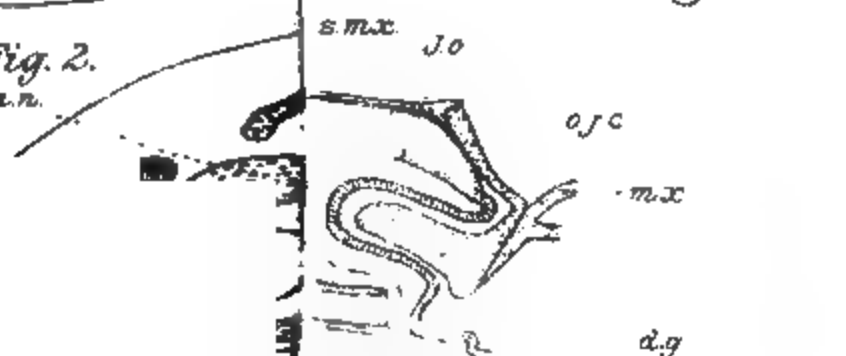
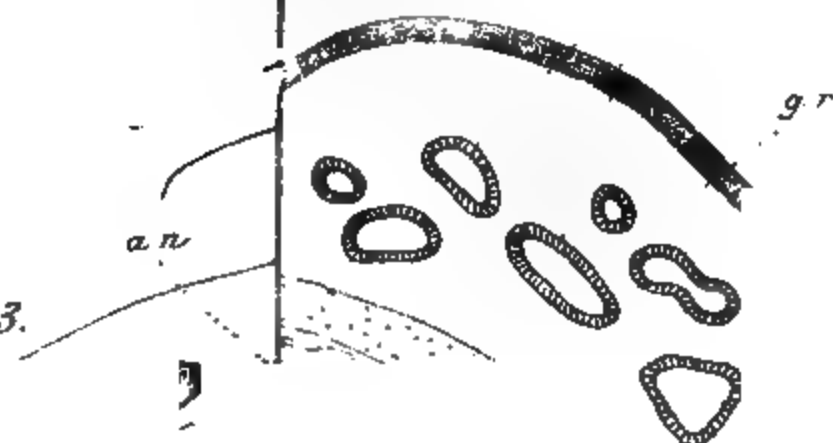


Fig. 3.

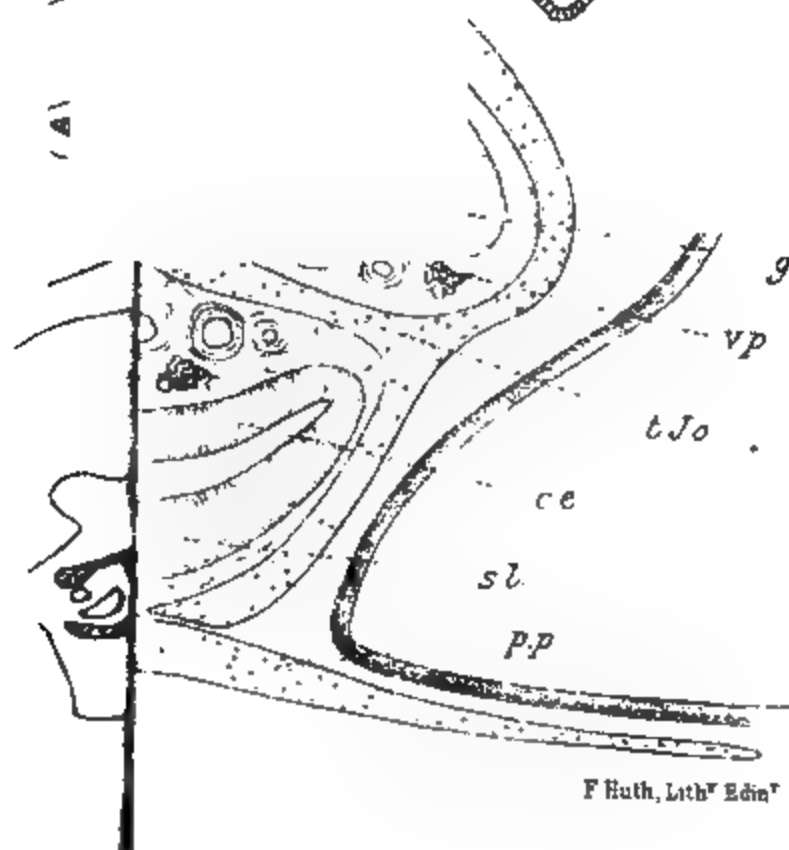
p.m.x.

a.n.



p.m.x.

Fig. 5



. a

F

x

F

x :

F

x €

c .

b



Fig. 1 Form of Beluga to

Fig. 2 Pectoral limb $\frac{1}{2}$

I

Fig. 3 Carpus, &c $\frac{1}{3}$



Journal of Anatomy and Physiology.

A DESCRIPTION OF TWO SYMELIAN MONSTERS.¹

By T. MANNERS-SMITH, B.A. (Cantab.), M.R.C.S., *Chief Demonstrator of Anatomy, Mason College, Birmingham.*
(PLATE V.)

THE occurrence of Symelian monsters is of sufficient rarity to make each case worthy of careful anatomical examination, with a view to a more complete classification, and, if possible, to throw some light upon the causation of this form of monstrosity.

Neglecting the fanciful descriptions of the teratologists of the sixteenth and seventeenth centuries, such as Lycetus, Lycosthenes, Palfin, and Rueffus, the first systematic description of these monsters, from a strictly objective and purely anatomical point of view, occurs in the writings of Haller, published between 1735 and 1753. From this period to the time of Saint-Hilaire, who was the first to elevate the study of monstrosities to the level of a science, various observations were made from time to time by Boerhaave, 1757; Sachsse, 1803; Otto, 1811; Dieckerhoff, 1819; Meckel, 1826; Cruveilhier, 1827; and Behn, the last observer, in his work *De-monopodibus*, was the first to point out that these monsters possessed only one umbilical artery. The principal contributions of the last half century are those of Vrolik, Solger, Gebhard, Odisio, and Benington, to which authors frequent reference is made in the text.

In the following account I have described the bones, muscles, and nerves of the two monsters coming under my notice, and I have compared their anatomy with that of many of the specimens of the above-mentioned authors.

Nomenclature.

Before the time of Saint-Hilaire, Symelian monsters were described somewhat loosely under the names Monopodia or Monopodia, names which, as Saint-Hilaire pointed out, it would

¹ Read before the British Medical Association, in the Section of Anatomy and Histology, London, Aug. 1895.

be better to reserve for those monsters possessing a single inferior extremity and foot. Other observers have adopted as a class-name for this family of monstrosities, the term *Sireniforma* or *Sirenlike*, from the fancied resemblance to the sirens of mythology. This name, as Saint-Hilaire has also pointed out, should be reserved for a certain variety of Symelian monsters only, namely, that without feet. Cruveilhier preferred the less correct but more picturesque and more easily intelligible descriptions, either *Monopodia* or *Sirens*.

Saint-Hilaire's classification was as follows:—(1) The two inferior extremities united, almost perfect, terminated by a double foot, the sole of which is turned in front: *Symèle* or *Symeles*, the *Sympus dipus* of other authors. (2) The two inferior extremities united, very incomplete, terminated by a single foot, almost always very imperfect, the sole of which is turned in front: *Uromèle* or *Uromeles*, the *Sympus monopus* of other authors. (3) The two inferior extremities united, extremely incomplete, terminated in a stump, or in a point without a distinct foot: *Sirénomèle* or *Sirenomeles*, the *Sympus apus* of other authors.

The specimens which came into my possession, through the kindness of Dr Windle, were two in number, one belonging to the class *Symeles*, the other to the class *Sirenomeles*; a third specimen, which at first sight appeared to belong to the class *Uromeles*, turned out, on dissection, to belong to the family *Monopodia*.

The Osseous System.

SPECIMEN I. There were thirteen dorsal vertebræ; thirteen ribs on the left side, six lumbar vertebræ.

SPECIMEN II. Lumbar vertebræ normal in number; last lumbar, however, articulated with the ilium. There was considerable right convex bending in the lumbar region.

In Gebhard's first specimen there was considerable **scoliosis**, with left convex bending in the dorsal region, right convex in the lumbar. The ribs and vertebræ were normal in number. In one of Vrolik's specimens there were eleven ribs on the right side; the normal arrangement on the left. In a second specimen

of the same author there were thirteen ribs, six lumbar vertebræ; the last lumbar vertebra was joined to the iliac shield. In one of Otto's specimens there were fourteen ribs on the left side; six only on the right. In a second specimen of the same observer there were eleven ribs on each side; five lumbar vertebræ; the last effected a movable articulation with the pelvis. In a third specimen sacrum and coccyx were absent, and pelvis articulated with the last lumbar vertebra. In a fourth there were eleven ribs and five lumbar vertebræ; the last effected an articulation with the pelvis. Thus, in most of the specimens examined and collected, the ribs were either diminished or increased in number on one or both sides of the body.

The iliac bones in the first specimen were well developed and separate. The ischia were fused, and the pubes normal. In the second specimen the ilia were fused into an iliac shield, the ischia were rudimentary, the pubes were fused and existed as a projection from the ilia. The femora and patellæ were separate in the first specimen; they were fused in the second. The fibulæ were fused in the first specimen, as also were the fourth and fifth metatarsal bones. The fused fifth rested on the dorsal surfaces of the fused fourth; both articulated with a bone resulting from a fusion of the two cuboids. The calcanea were the only other united bones of the foot; the remaining bones were normal in number. The bone resulting from the fused fibulæ was situated in the middle line between the two tibiæ. The fused calcanea articulated superiorly with the fused fibulæ, and inferiorly with the fused cuboids. Thus, the fibulæ, the calcanea, the cuboids, the fourth and fifth metatarsal bones, were all fused and situated in the median line of the leg and foot. In the second specimen the femora had met by their outer surfaces, and were fused into a single bone. The leg was only represented by a pointed process, resulting from the fusion of the upper ends of the tibiæ. The patellæ were also fused.

Specimens have been described by Vrolik, Otto, Cruveilhier, Solger, Gebhard, and Odisio, having an almost identical arrangement with that of the above two specimens. In other specimens, however, femora were more or less distinct above or below, and two patellæ and rudiments of two tibiæ were present.

If there is a diminution in any of the leg or foot elements, it

would seem to take place in a regular order, from the fibular to the tibial side. Thus, in some cases, all four leg bones are present; the fibulæ are, however, approximated. In other cases there is a single median bone situated between the two tibiæ, and resulting from a fusion of the two fibulæ. Again, fibulæ may have entirely disappeared, the tibiæ only being present, either complete and separate or incomplete and fused. Lastly, only a bony point may be present, resulting from a fusion of the upper ends of the tibiæ. In the foot, too, though with less regularity, the bones seem to diminish or disappear from the fibular to the tibial side. Thus, when only one or two digits are present, they are generally either one or both of the halluces. In the thigh, too, the femora meet by their outer surfaces, and may either unite throughout the whole extent of these surfaces, as in my second specimen, or may remain separate above or below.

The Muscular System.

The Gluteus maximus was normal in the first specimen. It appears to be present in most of the specimens examined, which belonged to the classes Symeles or Uromeles. In the second specimen, which belonged to the class Sirenomeles, it was absent. It was also absent in somewhat similar specimens of Vrolik and Calomiatti, and in Gebhard's second specimen. In Cruveilhier's specimen it was very slightly developed. The right and left muscles were fused in the region behind the anus. This fusion also occurred in the specimen described by Solger.

The Gluteus medius was normal in all respects in the first specimen. It was present in those specimens of the other observers, which belonged to the class Symeles or Uromeles. It had a partial intra-pelvic origin in the specimen described by Benington. In the second specimen the muscle was absent, as it was also in the specimens of the class Sirenomeles, examined by the other observers.

The Gluteus minimus had a partial intra-pelvic origin in the first specimen; it was absent in the second specimen. It appears to be present as a rule in the classes Symeles and Uromeles, whilst it is absent in the class Sirenomeles. A large mass of fat occupying the position of the gluteal muscles was

present in the second specimen. In this mass were found scattered muscular bundles, a circumstance which would raise the presumption that the fatty deposit represented the degenerated gluteal muscles.

The Pyriformis was present in the first specimen, and was absent in the second. It was absent in all the other specimens collected, excepting that of Cruveilhier, in which it was vestigial. Obturator internus was present in the first specimen. It was absent in the second, and in those of all the other observers, excepting in that of Odisio.

Superior Gemellus was absent in all the cases examined and collected, excepting in that of Cruveilhier, in which it was vestigial.

Inferior Gemelli were fused in the first specimen, and formed a narrow strip passing from side to side. They were absent in the second specimen, and in most of those of the collected cases. Quadratus femoris muscles were also fused into a transverse strip. They were present in Gebhard's specimens, but absent or vestigial in all the other cases examined and collected. Obturator externus was normal in most of the specimens examined and collected.

The long head of biceps, the semi-membranosus, and the semi-tendinosus, were all absent in both my specimens. Amongst the cases of other observers, in only two instances was the biceps complete, namely, in those of Cruveilhier and Solger. The short head only was present in my first specimen, and also in the specimen described by Benington. Semi-membranosus was present in Cruveilhier's specimen, and also in that of Calori.

The Semi-tendinosus was absent in all cases, excepting in that of Calori. Vrolik states that two only of the hamstring muscles were present: which two he does not specify.

Thus it will be seen from the above that, in all the cases examined and collected, the hamstring muscles were more or less deficient.

The adductor magnus muscles in the first specimen arose by a narrow tendon on either side of the triangular piece of bone representing the fused ischia. The lowest fibres of the muscles are inserted into the tibiae. The muscles of opposite sides are

connected intimately at their origin, and by a thin membrane, in the middle portion of the thigh. In the second specimen the adductor magnus is fused in the middle line with the muscle of the opposite side. These muscles are found in all the cases of the other observers, and in the cases of Solger and Benington they were arranged very similarly to those of the first specimen examined by me. They are, as a rule, more or less united. Of the eleven specimens examined and collected, only in that of Calori did the adductor longus, adductor brevis, and pectineus fail. Gracilis was absent, also, only in the specimen of the latter observer. Psoas and iliacus were normal in both my specimens, and were present in most of the specimens collected. Sartorius was normal in the first specimen, but, in consequence of the peculiar position of the tibia, the insertion of the muscle did not cover, but was covered by the gracilis. In the second specimen, sartorius had the normal origin; but, in consequence of the peculiar rotation of the ilium downwards and backwards, its origin is situated more posteriorly than usual. The muscle keeps to the outermost portion of the limb, as far as the knee-joint, where it curves slightly inwards, and is inserted into the rudimentary tibia, its insertion being covered by that of the gracilis muscle, as in the first specimen. It was present and normal in all the cases collected. The rectus femoris was normal in both my specimens. The vastus externus was normal in its origin and insertion, but, in consequence of the peculiar position of the limb, was situated on the posterior surface. The vastus externus muscles of the second specimen were fused and situated in the middle line of the thigh. The vastus internus and crureus were normal in both my specimens. The above muscles were present and normal in most of the specimens collected.

Of the specimens examined and collected, in four only was the leg and foot present, namely, in my first specimen, and in those of Solger, Benington, and Cruveilhier.

Peroneus longus muscle arose by two heads, the heads embracing the insertion of the short head of the biceps. The heads of the muscle are continuous with the insertion of the biceps. The heads blend just below the upper extremity of the bone resulting from the fusion of the fibulæ, and the muscular

bellies arise from the upper third of either side of that bone. The muscles of opposite sides were fused at their origin and again on the dorsum of the foot. The muscles passed down in the middle line on either side of the fused fibulæ. On the dorsum of the foot, the tendon of each muscle divides into two parts; the median portion unites with a similar tendon from the muscle of the opposite side, and forms an expansion over the dorsal surface of the fused fifth metatarsal bones. The lateral portion of the tendon of each muscle passes deeply, and is inserted partly into the base of the fused fourth metatarsal bones on its own side, and, in addition, sends a slip to the base of the third. In the sole, the tendons of the muscles of opposite sides are fused into a transverse tendinous band, which passes from the base of the first metatarsal bone of one side to that of the other. From this band, adductor hallucis of each side arises. No connection could be traced between the dorsal and plantar tendons of the peroneus longus. Between the two heads of origin of the peroneus longus passes the peroneal nerve. The muscles were present in all the four cases mentioned above. They had a similar origin to the above in Solger's specimen, but were inserted into the os calcis.

Peroneus brevis arises from each side of the bone representing the fused fibulæ. It possesses a thin tendon, which passes down and is inserted on either side of the bone representing the fused fifth digits. It was present in the specimens of the other three observers. Peroneus tertius is absent. It is mentioned by Solger, but by neither Benington nor Cruveilhier.

Extensor communis digitorum sends a slip to the hallux. There is, however, no slip from the brevis to this bone. Another tendon of the muscle divides for the second and third digits. The innermost tendon, which is large, passes to the bone resulting from the fusion of the fourth digits.

Tibialis anticus is divided into two heads above. The median arises from the head of the tibia. The lateral is continuous with the insertion of the rectus into the tubercle of the bone. The muscle has the usual origin from the shaft of the tibia. At the foot, the muscles of opposite sides were fused into an aponeurosis, from which, slips passed to the usual bones.

Extensor longus hallucis arises from either side of the fused

fibulæ. The muscle is joined by the outermost tendon from the extensor communis digitorum, and the combined tendon is inserted, partly into the first, and partly into the second phalanx of the hallux. The slip from the extensor communis probably represents the extensor brevis hallucis. The extensor communis digitorum, tibialis anticus, and extensor longus hallucis were present and distinct in the specimens of Solger, Benington, and in my own, whilst, in Cruveilhier's specimen, the three muscles were fused into a fleshy mass, from which tendons were given off proper to each toe.

Extensor brevis digitorum has three slender tendons. The innermost passes to its own side of the fourth fused digits; the remaining two tendons pass to the second and third digits. The muscle was present in all the four cases mentioned above, though one or more of its tendons may be suppressed.

Gastrocnemius and soleus were absent. Rudiments only of gastrocnemius were present in the specimens of Solger and Benington. Soleus was present in Solger's specimen, but absent in that of Benington. In Cruveilhier's specimen rudiments only of these muscles were present. They were not inserted into the bone, but ended in the subcutaneous fat.

Popliteus has the usual origin. Its tendon, however, passes towards the median line, crossing the transverse portion of a T-shaped band. This band passes across from femoral condyle to condyle. The vertical portion of the T passes to the head of the fused fibulæ. The tendons of the two poplitei muscles, approaching each other above the transverse band, are connected here by a short fascial slip. Each muscle now passes outwards, and is deeply situated owing to its insertion into the external condyle, the position of which in this case is rather postero-internal, in consequence of the failure of the lower end of the femur to rotate.

Flexor longus digitorum and Flexor longus hallucis are fused. The fused muscles arise chiefly from each tibia, and, more internally, from the posterior surface of the fused fibulæ. The muscles of opposite sides blend in their upper fourth in a tendinous raphé in the middle line. The tendons of each side pass downwards as far as the ankle joint, where they expand and fuse. The tendinous expansion resulting from the fusion divides

into six tendons, three for each side. The first, which is slightly larger than the others, passes to the hallux. It represents the flexor longus hallucis, and its tendon may be traced into continuity with the fibular portion of the fused muscle. The other two tendons pass on each side to the second and third digits, and, after perforating a slender flexor brevis, pass to be inserted into the terminal phalanges of those digits. The bones resulting from the fusion of the two fourth and the two fifth digits have no flexor tendons passing to them. In the specimen of Solger the flexor longus digitorum was also fused with the muscle of the opposite side. The flexor longus hallucis was present and normal on the right side. The muscle was absent, however, on the left. In Benington's specimen both muscles were present and normal. In the specimen of Cruveilhier the flexor longus digitorum was present, but no separate flexor hallucis.

Tibialis posticus arose from the tibia and fibula, the fibular portion blending with the muscle of the opposite side in a tendinous raphé. The tendons of the muscles passed down to the ankle, where they blend with each other. From the expansion resulting from the fusion, one head of flexor brevis digitorum arises. The muscle was present in the three cases of the other observers.

Flexor brevis digitorum arises by two heads; the outer from the tendon of the tibialis posticus, in company with the abductor hallucis: the inner head from the aponeurosis, which results from the fusion of the tibiales postici. The muscle divides into two tendons, which become the perforatus for the second and third digits. No tendons pass from this muscle to the fourth or fifth digits. The muscle was present in Solger's specimen, and arose from the plantar aponeurosis. In Cruveilhier's specimen the muscles of the foot were represented by only a few fleshy bundles, which he states it was impossible to unravel.

Abductor hallucis was present and arose from the tendon of the tibialis posticus.

Flexor brevis hallucis arose from the tendon of the tibialis posticus, as well as from the usual tarsal bones. Adductor hallucis obliquus arose from the fused transverse tendons, which represented the plantar part of the peroneus longus muscles.

There is a slender adductor transversus present.

Nerve Plexuses.

Lumbar Plexus.—In specimen I. the usual branches are present, though there is a difference in the origin of some of them upon the two sides. Thus, on the right side, the anterior crural has the normal origin. On the left side it arises from the third, fourth, and fifth nerves. Most of the fifth nerve joins the anterior crural, a small portion only passing to join the lumbo-sacral cord. In Gebhard's specimens the anterior crural was normal in its origin but was smaller than usual in his first specimen. In specimen II., on the right side the anterior crural arises in the normal manner. On the left side, this nerve takes origin from the second, third, fourth, and fifth lumbar nerves. Thus, in both my specimens, the anterior crural was normal on the right side, and received a branch from the fifth nerve in both cases on the left side. It is, perhaps, as well here again to draw attention to the fact that, in one of the specimens, there were thirteen ribs on the left side, and in the same specimen six lumbar vertebræ. In one of the above specimens too, the last lumbar vertebra articulated with the ilium. Though perhaps somewhat foreign to the subject, the above observations are interesting in connection with the views of Rosenberg, who explains the presence of additional vertebræ as a reversion to what he regards as an ancestral condition. The suppression of a movable vertebra, *i.e.*, the conversion of a lumbar into a sacral, is an arrangement which he looks upon as the coming form of vertebral column. As Paterson has stated, the nerve relations would help to confirm the above view. In one of my cases, presenting an additional lumbar vertebra, the nervus bigeminus was the second sacral nerve instead of the third.

The obturator nerve was normal on both sides in the first specimen. It was normal also in Gebhard's specimens. In the second specimen the obturator nerve was normal on the left side. On the right it arose from the second, fourth, and fifth lumbar nerves, and also received a branch from the first sacral.

Sacral Plexus.—In the first specimen there is a single great sciatic nerve, which is formed by the union of the lumbo-sacral elements and the first two sacral nerves of each side. They unite just outside the pelvis, and the single nerve passes to the

lower third of the thigh, where it divides into three branches, *i.e.*, the two peroneal nerves, and a nerve representing the combined posterior tibials. These nerves give off the usual muscular branches. There is a difference in the arrangement of the lumbo-sacral elements on the two sides. On the right side the nerves representing the lumbo-sacral cord are a slender branch from the fourth and the whole of the fifth lumbar. These nerves do not, however, unite to form the usual cord, but, after communicating with each other, join the great sciatic separately outside the pelvis. On the left side, most of the fifth nerve joins the anterior crural. A small portion only passes into the pelvis to join the lumbo-sacral cord. No fibres pass from the fourth nerve to the cord, and, in consequence, this cord, and, in fact, the whole sacral plexus on this side is much smaller than on the right.

The sacral plexus is much larger on the right side than on the left, in consequence of the above-mentioned arrangement of the lumbo-sacral portion. The only other nerves entering into the plexus were the first and second nerves. There is no trace of any other sacral nerves present; consequently the lower portions of the sacral plexus and the pudendo anal plexus are absent.

The gluteal nerves, and the branches to those muscles which existed were present.

Solger describes, in the place of the great sciatic nerve, two unequal sized strings, which can be seen to come from a single stem in the pelvis. That, again, consists of two bundles; the right string divides into anterior tibial and right peroneal, the left into posterior tibial and left peroneal. In Cruveilhier's specimen the two internal popliteal nerves were fused into a single trunk, which commenced at the lower part of the pelvis. The two peroneal nerves were quite distinct.

In my second specimen the nerves of the sacral plexus were rudimentary, and resembled flattened fibrous bands. They ended in the fascia of the pelvis; the right sprang from the second sacral and was small. The left was derived from the fifth lumbar and the first and second sacral. It appeared as though the nerves had been compressed by the fusion of the iliac bones. In Gebhard's first specimen, great sciatic nerves were absent on both sides: in his second specimen there were no sciatic nerves, but several

gluteal nerves were present. In Calori's specimen the sacral plexuses were wanting. In Calomiatti's specimen the sciatic nerves were very small. Most probably this diminution in size, or this absence of the sacral plexus described in the above specimens, is a secondary change due to compression by the iliac bones.

Summary of the chief interesting Anatomical Peculiarities of the Specimens examined and collected.

1. The frequent abnormality in the number of the vertebræ.
2. Articulation of last lumbar vertebra with ilium.
3. The scoliosis frequently found in the lumbar or dorsal regions.
4. The unsymmetrical condition of the ribs.
5. The ilia appear to be as a rule, separate in Symeles, but fused in Sirenomeles.
6. The rudimentary condition of the ischia and pubes.
7. Patellæ separate, as a rule, in Symeles: fused in Sirenomeles.
8. Fusion of the femora by their outer, not by their inner surfaces.
9. The diminution of the leg and foot elements from the fibular to the tibial side.
10. The absence of the gluteal muscles in the specimens belonging to the class Sirenomeles.
11. The partial intra-pelvic origin of one or other of the gluteal muscles.
12. The frequent absence or diminution of the small external rotator muscles.
13. The almost constant absence of one or other of the hamstring muscles.
14. The absence or rudimentary condition of the calf muscles.
15. The fusion of the flexor longus digitorum with the flexor longus hallucis.
16. The fact that the nervus furcalis is in some cases the fifth lumbar nerve instead of the fourth on one or both sides, together with the fact that in one of the same cases there were thirteen ribs on the left side and six lumbar vertebræ.

17. The unsymmetrical condition of the sacral plexuses.
18. The fusion of the elements of the great sciatic nerves.
19. The rudimentary condition of the sacral plexus in the specimens belonging to the class Sirenomeles.
20. The fusion, in almost all cases, of like parts.

THEORY AS TO CAUSATION.

Saint-Hilaire explained the formation of these monsters by what he termed the law of affinity of like for like (*Loi de l'affinité de soi pour soi*); that is to say, that the union was what he described as "a natural" process, and quite as natural a process as the union of other parts, which at first paired and were lateral, afterwards became united. That the reason why the extremities do not as a rule unite, was because they never have the opportunity of coming into contact. In favour of this view, he quotes the fact that the upper extremities are never found united, in consequence of the thoracic cavity intervening; that, normally the lower extremities are separated in a somewhat similar manner, though not to the same extent, by the pelvic elements; but that these, failing in some cases, the lower extremities are able to come in contact, and, as a result of this, fusion takes place. He states that we should rather wonder that union does not more frequently occur, than that it occurs only occasionally. Cruveilhier, though expressing his admiration for the above view, points out that the foetal lower extremities are frequently in contact without union occurring. The same observer criticises adversely the view of Meckel, namely, that this class of monstrosity was due to an original malformation of the germ. Cruveilhier himself adopts the view that both the fusion and the rotation are due to pressure, both lateral and antero-posterior. Tiedermann and Serres considered the condition due to deficient arterial supply, the latter attributing it as due especially to absence of one of the umbilical arteries. Vrolik, after condemning the idea that this condition is due to absence of one of the umbilical arteries, and pointing out that one artery only is sometimes observed, both in the completely well-formed foetus, as well as in double monsters, states that sympodia is due to some original malformation of the pelvis and its viscera, of which the

cause remains unknown. He does not even admit that the condition is due to a fusion of the extremities, and states that the regularity of transition of one form into another, *i.e.*, from simple abnormality of position, to fusion with more or less absence of structure, makes it impossible to ascribe the condition to accidental external causes. Solger explains the single umbilical artery as a continuation posteriorly of that process of fusion which forms the single dorsal aorta. He also explains the fusion of the limbs, by an approximation of the side plates from which the limbs are developed, and, as a result of that approximation, fusion takes place. In this way he explains the blind condition of the rectum found generally in these monsters.

Gebhard believes that the fusion is due to compression by the amnion.

Camille-Darest believes that, in consequence of the non-development of the caudal end of the embryo, the limb buds, instead of descending upon the two sides of the body, are reversed, and placed beneath the extremity of the embryo; coming into contact by their external border, they unite and form a single member.

In the absence of any direct knowledge as to the process of fusion, it seems to me that the theory of Saint-Hilaire, interpreted in the light of modern biological research, is the one which is the most satisfactory, *viz.*, that there is an inherent tendency for the side plates or limb buds to unite, an affinity of like part for like part, understanding by affinity nothing more than a greater tendency for similar than dissimilar parts to fuse. That this tendency is latent, and is comparable to, and is possibly the descendant of, that fusion, which (adopting the most recent view as to the origin of paired and unpaired limbs) takes place in the posterior portion of the fin elements of certain fishes. Thus, it has been shown by Dohrn and Balfour that each somite gives rise to a fin element, each of which consists of two dorsal and two ventral bundles of muscle, two rods of cartilage and a corresponding spinal nerve. Both pectoral and pelvic fins are made up of a considerable number of these fin elements. These outgrowths are present along the entire length of the lateral epiblastic folds, and, while these abort between the pectoral and pelvic fins,

they converge and form the ventral unpaired fin in the region behind the anus, so that the ventral unpaired fin may have been originally paired, when the post-anal gut of the embryo and the coelome extended throughout the whole caudal region. Without entering into the vexed question of the relationship of the fin of the fish to the limb of the higher vertebrates, and the homologies of these parts, I mention the above simply in support of the tendency to fusion-theory of Saint-Hilaire, that is, of parts which, at first, paired and lateral, afterwards become median and united, and in support of the extension of that theory to limb elements. Whether this tendency in the case of Symelians is called into activity by pressure or by failure of the limbs to rotate properly, or whether it has its origin in the tilting of one limb towards the other, in consequence of an unsymmetrically developed or articulated pelvis, there is no evidence, but from the unsymmetrical condition of the sides of the whole body, that is, of ribs, vertebræ, and pelvis, in many of the cases in which a careful description has been given, I should be inclined to favour the view that the last-named condition is the exciting cause. From the fact that only similar elements are united, and that all transitions are met with from instances where there is simple union of the feet, without absence of any of the limb elements, to those in which the leg is represented only by a stump-like extremity, together with the fact that the different species fall into definite classes, agreeing so exactly in their structure, it would seem that the pressure-theory alone is insufficient to account for the condition, unless there is some such affinity for like parts as Saint-Hilaire described. But, in whatever way the exciting cause has been set up, the fusion itself is possibly the result of a latent tendency, that tendency having been transmitted to the limb-bud from its homologous representative in certain piscine vertebrates.

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EXPLANATION OF PLATE V.

Figs. 1, 2, and 3 represent the first specimen—Symeles.

Fig. 1. Shows the bones of the first specimen; the posterior surface of the ilia is shown, and the fused condition of the ischia. The leg and foot are rotated in a direction opposite to the normal, so that the anterior surface of these is directed posteriorly. The bone situated between the two tibiæ represents the fused fibulæ. The bones situated in the median line of the foot represent fused calcanea, cuboids, and fourth and fifth metatarsal.

Fig. 2. Is the same view as Fig. 1, but shows the arrangement of the muscles.

Fig. 3. Shows the muscles of the anterior surface of thighs and pelvis and the muscles of the posterior surface of the leg and foot, the legs being rotated in such a way that these latter muscles look to the front: it also shows the lumbar and sacral plexuses.

Fig. 4. Sirenomeles. This represents the bones of the second specimen; it shows the ilia fused into an iliac shield, and the union of the femora and the rudimentary tibæ of opposite sides. The bones are seen from their posterior surface.

Fig. 5. This represents the muscles and nerves. Same specimen as Fig. 4, seen from the anterior surface.

MORPHOLOGY OF THE TRUE "LIMBIC LOBE," CORPUS CALLOSUM, SEPTUM PELLUCIDUM AND FORNIX. By G. ELLIOT SMITH, M.D., Ch.M., *Demonstrator of Anatomy, University of Sydney, N.S.W.*

(Concluded from p. 167.)

The "precommissural area" of the median cortex.

IN the foetal Platypus, as in the adult Sauropsidan and Amphibian, a broad sheet of grey matter ("the precommissural area") extends backwards from the mesial wall of the bulbus olfactorii, and, crossing the mesial plane in front of the foramen of Monro to become continuous with the corresponding region of the opposite side, forms the lamina terminalis ("lamina infra-neuroporica" of Burckhardt).

As there is no satisfactory term by which to distinguish this region, I have called it "precommissural area," a term which is purely descriptive and does not imply any homology. The area in question corresponds to what Herrick, in reptiles and *Didelphys*, has called "intraventricular lobe"—a term to which there are obvious objections. Dorsally the region is continuous with the fascia dentata, and ventrally with the tuberculum olfactorium. Posteriorly it is directly continuous with that part of the lamina terminalis which lies between the anterior and fornix commissures. It forms part of the "posterior olfactory lobule" of His. In the ontogeny of the mammalian brain it develops early and forms a relatively huge mass, which bulges into the lateral ventricle, and vividly recalls the appearance of the homologous area in the Amphibian brain (the "callosal eminence" of Gage and Fish). In reptiles the homologue of this region has been called "Fornix Leiste" by Edinger. It corresponds, in part, to the "septum pellucidum" of Adolf Meyer, in certain reptiles. In the development of the cerebrum of the Proto- and Meta-theria, the "precommissural area" is gradually encroached upon by the curving downwards of the anterior extremity of the hippocampus and pallium, so that its anterior

connection with the olfactory bulb is reduced to a narrow tract near the base of the brain, which is often distinguished by the inappropriate name of "mesial" or "internal olfactory root." In Eutheria the pallium encroaches upon this region in the same way, and its anterior limit is indicated by the "vordere Bogenfurche" of His. The "precommissural area" in the foetal cat has been called the "area trapezoides" by Paul Martin.

The precommissural area is phylogenetically extremely ancient, and probably reaches its maximum relative development in the Amphibia. It is intimately connected with the olfactory apparatus, and is characterised in all animals by its simple amorphous structure, and by the fact that it transmits fornix fibres—the precommissural fibres of Huxley. In placental mammals the enormous development of the surrounding parts throws this region into insignificance; and in the higher animals it undergoes an actual reduction by sharing in the general atrophic process which affects the whole olfactory apparatus. It corresponds to the "gyrus subcallosus" of Zuckerkandl, a structure which is known in human anatomy by the extremely inappropriate name, "peduncle of the corpus callosum."

The Tuberculum olfactorium.

On the basal aspect of the cerebrum of Platypus, on either side of the middle line, there is a small elliptical prominence situated immediately behind the olfactory bulb, and on the mesial side of the anterior extremity of the pyriform lobe. Hill would not venture to name it, but concluded by excluding it from the rhinencephalon. The homologous region in other animals has been distinguished by quite a variety of names, of which I select that used by von Koelliker as the most appropriate. It corresponds to the "espace quadrilatère" "*racine moyenne ou grise* (du lobe olfactif)" of Broca. Although the lenticulo-striate arteries do not perforate this region in lower mammals, still it is homologous with that atrophic area which in the human brain constitutes the "*locus perforatus anticus*" of Vicq-d'Azyr. Edinger calls it the "*Riechfeld*," and Herrick calls the homologous area in *Didelphys* and reptiles "the *post-rhinal lobe*." In *Dasypus sexcinctus* Turner has called it "*orbital*

lobe." It consists of a small patch of grey matter, which varies in size and prominence with the olfactory bulb. Thus it is relatively small in *Platypus*, and although larger in *Echidna*, the enormous development of pallium around it throws it into insignificance. The same may be said of the highly macroscopic *Macropus*, *Petrogale*, *Hypsiprymnus*, and *Thylacinus*. It is flat and insignificant in *Petaurus* and *Phalangista*, corresponding to their smaller olfactory apparatus. It is somewhat larger in *Phascolarctos*. In *Dasyurus* it appears as a well marked rounded prominence. In *Perameles* it is relatively much larger still, and probably reaches its highest relative development (for a mammal) in *Notoryctes*. In the small marsupial mole it forms a large rounded mass, which forms a complete hemisphere projecting from the base of the brain, and almost equalling in size the natiform eminence. It almost extends to the lateral border of the hemisphere. In the reptile the corresponding region is very large, and not only forms a large area of the base, but extends well on to the lateral aspect of the cerebrum.

The surface of the region is pale, from the presence of a number of medullated fibres arising from the external olfactory radiation, and terminating in the region.

The tuberculum olfactorium extends on to the mesial surface of the hemisphere, and becomes continuous with the precommissural area. Dorsally, this region is directly continuous, on the outer side of the lateral ventricle, with the corpus striatum, with no clear line of separation between them. Hence Ganser called it the "*Kopfes des Streifenhügels.*"

The three parts of the "pars intermedia" of the limbic lobe—the precommissural area, the tuberculum olfactorium and the septum lucidum—resemble one another in their general histological features. They all lack the characteristic cortical structure, and contain small scattered polymorphous cells. They are, moreover, phylogenetically the most ancient parts of the cortex cerebri, and accordingly are much more prominent in lower vertebrates, especially the higher Amphibia and reptiles. They also present a markedly precocious development in the mammal.

The hippocampus appears in phylogeny after these regions, the fascia dentata probably preceding the cornu ammonis

(hippocampus major); and probably the pyriform lobe appears immediately after the hippocampus. The pallium is the last part to appear, and can only be certainly recognised in the mammalian cerebrum. After subtracting the hippocampus, tuberculum olfactorium, and precommissural area—all of which can be fairly easily recognised—from the sauropsidan cortex, there is a very small area left to homologise with the pyriform lobe and pallium. This small region upon the lateral aspect of the cerebrum is probably mainly or wholly pyriform. The cortex cerebri of the reptile, therefore, is homologous with the true limbic lobe mainly—possibly wholly.

The Phylogeny of the Corpus Callosum and Septum Pellucidum.

In the higher Ichthyopsida, Sauropsida, and non-placental mammals, the lamina terminalis contains two commissural bands (figs. 1, 6, and 7)—a dorsal and a ventral. The ventral band (fig. 6, *a.c*) is found in all vertebrates, and occupies a constant situation in the lamina terminalis. There can, therefore, be no question of its identification in any animal of this large series, not only from its position in Burckhardt's lamina infra-neuroporica, but also by the course of its fibres beneath the lateral ventricle. At first it connects only the corpora striata and olfactory bulbs (the prosencephalic part), but later the pyriform lobes and pallium.

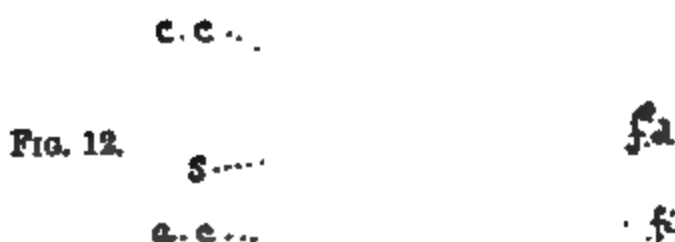
The dorsal commissural band (fig. 6, *f.c*) is the *fornix commissure*, and forms the link not only between the hippocampi and fasciæ dentatæ, but also between the precommissural areas of the two sides.

That part of the lamina terminalis which is situated (fig. 6, *s*) between the two commissures, becomes thickened early in development, especially in the mammalian brain.

In the development of any non-placental mammal¹ the fornix fibres cross the median plane in the most dorsal part of this thickening, and soon form a rounded bundle, just like that of the reptile (fig. 6). As development proceeds and the hemisphere elongates, the fornix commissure undergoes a correspond-

¹ I have examined foetal brains of *Ornithorhynchus*, *Perameles*, *Macropus*, and *Phalangista*, and am now engaged with those of *Echidna* and *Dasyurus*.

ing horizontal elongation from the crowding of more fibres between those already there. Although in *Platypus* and *Echidna* this elongation is not apparent (fig. 1, p. 159) in the



middle line, the arrangement of the fibres is clearly seen in a sagittal section of the median hemisphere wall (fig. 8).

There is thus produced an elongated dorsal commissure lying in the dorsal part of the lamina terminalis.

Corresponding to the caudal flexion of the hippocampus in *Ornithorhynchus* (fig. 2, p. 162), the fornix commissure assumes a shape (fig. 8) roughly resembling that of the hippocampus. In *Echidna* the posterior limb of the fornix commissure is better developed, corresponding to the larger descending limb of the hippocampus (fig. 3). In the marsupial the fornix commissure now consists of a distinctly bilaminar form corresponding to the complete flexion of the hippocampus (fig. 4). Thus in *Perameles* (fig. 9) the commissure consists of two widely divergent limbs which meet posteriorly in a "splenium." The ventral limb (*f.c''*) is formed from the fimbria (*fi*), which is derived from fibres proceeding from the descending portion of the hippocampus. The dorsal limb (*f.c'*) consists of fibres derived from the dorsal or horizontal part of the hippocampus. As this commissure elongates (fig. 10), the angle between the two limbs of the commissure becomes gradually more acute until in *Macropus* the two laminae are almost parallel.

The thickened mass of the lamina terminalis (*s*) completely fills up the "hook" formed by the fornix commissure. The fornix commissure of the non-placental mammal develops in this thickened mass, and in its fully-developed form (figs. 9 and 10) forms the dorsal and posterior boundaries of the thickening (p. 189).

The shape of the thickening is determined by that of the developing commissure. Lying immediately upon the dorsal aspect of the dorsal limb of the commissure in all the non-placental mammals is the fascia dentata.

As in the subsequent discussion I shall have frequently to refer to that portion of the lamina terminalis which is situated above the anterior commissure, and contains the fornix commissure and later the corpus callosum; and from whose thickening and subsequent stretching the septum pellucidum is developed, it will be convenient to have some shorter and less cumbrous term.

One is not justified in calling it "septum pellucidum," although the latter structure develops from it.

I shall therefore refer to it as the "*commissure-bed*," and shall understand by that term all that part of the lamina terminalis which lies on the dorsal aspect of the anterior commissure and which subsequently becomes thickened.

The literature relating to the development of the corpus callosum has been greatly enriched by the recent researches of Marchand and Paul Martin, who have studied respectively the human and the feline cerebrum. The result of their work has been to considerably modify the generally accepted opinion which regarded the corpus callosum as a development in the fused hemisphere walls. The rapid changes which occur in the development of the large commissural apparatus in any higher mammal are apt to obscure many of the essential features and thus deceive the observer. Thus Martin, summing up the results of recent work, still speaks of a *gluing-together* of the hemisphere walls, and Adolf Meyer speaks of the corpus callosum as a development in the *secondary fusion* of the hemisphere walls.

In this paper the subject is viewed from the broad comparative aspect. The general principles of growth have been studied in the non-placental mammal, and the facts collected by Mihalkovics, Marchand and Martin have been compared with the stages of development as they are exhibited in a series of Mammalian brains.

It may be stated at once that the idea of a fusion of the hemisphere walls is utterly opposed to the facts of comparative anatomy, which clearly point to the corpus callosum as a development in the thickened lamina terminalis, to which it morphologically belongs in all Eutheria.

In all animals below the Eutheria the fibres of the dorsal commissure are derived solely from the hippocampal formation. But in the Eutheria a new factor comes into play. Fibres derived from the pallium immediately adjacent to the hippocampus, and whose homologues pass through the anterior commissure in the Metatheria, now follow the same route as the fibres of the dorsal limb of the fornix commissure. These fibres, which constitute the *corpus callosum*, cross the mesial plane immediately on the ventral aspect of the fascia dentata, *i.e., in the thickened lamina terminalis*. When this occurs, the hippocampus in this region atrophies, so that the dorsal limb of the fornix commissure disappears. Thus it appears that in the Eutheria, fibres belonging to the anterior commissure system (and which constitute the corpus callosum) usurp the place of the dorsal limb of the fornix commissure of the Metatheria and

pass through the dorsal part of the thickened lamina terminalis (fig. 11), which is now recognisable as the homologue of the septum pellucidum of higher mammals. The remains of the hippocampus may be seen as the *gyrus supracallosalis* of Zuckerkandl (fig. 11, *g.c*), which presents the same relation to the corpus callosum as the hippocampus does to the dorsal limb of the fornix commissure in the marsupial (fig. 9).

The Eutherian cerebrum is already well flexed when the dorsal commissure first begins to develop. True to its phylogenetic history, the fornix commissure is the first part to develop, which it does in the thickened lamina terminalis (Paul Martin). When the proper callosal¹ fibres appear they form, with the fornix commissure, a small arc, *lying in the thickened lamina terminalis*, and corresponding to the bend of the hemisphere. As fresh fibres crowd in between those already present, the commissure elongates, *i.e.*, the arc increases in size. As it extends it must stretch the lamina in which it lies, so that, just as in the marsupial, the shape of the rudimentary septum is determined by that of the dorsal commissure.

In lowly Eutheria such as most of the Edentata and in highly macrosmatic mammals with a small pallium such as the mole, whose brain has been so admirably described by Ganser, the corpus callosum presents features not unlike that found in the early stages of the higher mammalian brain. The small band which forms the dorsal commissure in these lowly mammals lies in the dorsal part of the thick mass, which is readily recognised by comparison, as part of the lamina terminalis—the “*commissure-bed*.” In such animals this thickening becomes continuous on either side, just as in the marsupial and monotreme, with the thick mass of the precommissural area. These two regions—precommissural area and rudimentary septum—are simply parts of one great sheet, which presents uniform histological features. Both regions transmit fornix fibres and both parts vary in their development with the olfactory apparatus.

¹ Martin does not distinguish between a corpus callosum and a fornix commissure, calling the combined commissure “corpus callosum.” Both for convenience of description and also for morphological reasons, it is desirable to distinguish between a fornix commissure and a true corpus callosum.

Now, just as in the ascending scale the importance of the precommissural area diminishes, so also does that of the thickened mass of the lamina terminalis. Thus, in the mammalian series, as the corpus callosum is rapidly increasing in extent, the "*commissure-bed*" is diminishing in extent with the lessening importance of the olfactory sense.

These two opposing factors have very important effects upon the morphology of this region in the higher mammals. *The stretching of the thickened mass of the lamina terminalis by the extending arc of the dorsal commissure produces the septum pellucidum; and as a physical expression of the antagonism between the extension of the commissure and the retrogression of its "matrix" the cavum septi pellucidi or fifth ventricle appears.*

In many of the lower Eutheria in which, being macrosmatic, the "*commissure-bed*" is large, and the pallium small, the two factors do not come into opposition. Thus in *Talpa* (Ganser), *Dasypus* (Turner), and *Cholæpus* (Flower), the commissure is not sufficiently extensive to affect the large mass of the lamina terminalis.

In the rabbit, however, one may already see evident signs of the tendency of the growing corpus callosum to extend beyond the rudimentary septum. Thus, while the grey mass still fills up the greater part of the angle between corpus callosum and fornix commissure, the anterior extremity of the former is growing forwards and stretching the part of the lamina in which it

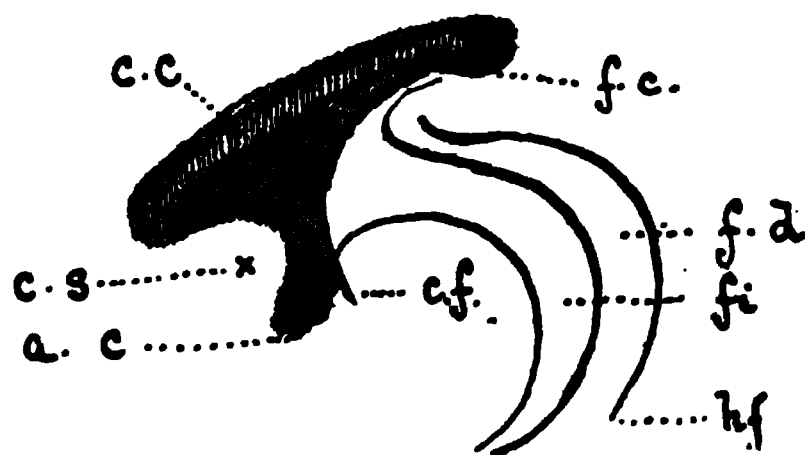


FIG. 13.—Scheme of commissures in rabbit.

lies. There is thus produced (fig. 13, *c.s.*) a depression widely open in front, and roofed above by the anterior extremity of the corpus callosum. The lateral walls of this depression are formed partly by a stretching of the thickening of the lamina terminalis, and possibly in part by the precommissural area. In many

mammals with a large pallium, and therefore a large corpus callosum, a large development of the lamina terminalis may for a time almost keep pace with the growing commissure. This applies, of course, to highly macrosmatic mammals. Thus in many carnivores the angle between the corpus callosum and fornix commissure may be largely filled up with "septum," so that there is only a small, or perhaps no "*cavum*."

In Man, however, the two opposing factors reach their climax. In the human brain the corpus callosum reaches its maximum size, whereas the "commissure-bed," in common with the rest of the olfactory apparatus, is undergoing a retrograde evolution. There is a maximum of fibres and a minimum of "matrix," so that the latter here becomes stretched to its uttermost.

When the corpus callosum first appears in the Eutherian foetus it presents a curved outline in sagittal section corresponding to the shape of the parts it connects. The inferior and posterior limb is fornix, being derived from the descending horn of the hemisphere in which the anterior and fornix commissures maintain their primitive arrangement, undisturbed by corpus callosum. The dorsal limb of the small arc is corpus callosum proper. As new fibres crowd in between those already formed, the arc increases in length and in diameter, *i.e.*, it tends to recede from the anterior commissure. In the higher or microsmatic mammal, a time soon arrives when the growing commissural arc reaches the limits of the small thickening of the lamina terminalis. In tracing the development, the lamina appears therefore to atrophy, but this apparent atrophy is largely, if not wholly, relative. The lamina becomes moulded to the shape of the commissure by the growth of the latter, so that at an early stage in the developing microsmatic mammal, the dorsal commissure consists of a small arc of fibres, with a thin layer of grey matter inclosing them, and accurately adapted to the shape of the commissural arc. There is thus early produced a small recess roofed by corpus callosum (lying in the lamina terminalis), bounded posteriorly and below by the fornix commissure (also inclosed in lamina terminalis), and laterally by walls also formed from the stretched lamina terminalis. This small recess, which is freely open in front, so as to communicate with the great longitudinal fissure, is the rudiment of the "*cavum septi pellucidi*."

As the commissure increases in extent by the addition of new fibres, the stretching of the lamina terminalis still goes on, so that as the corpus callosum grows back the cavum increases in extent, and the "laminae septi pellucidi" become broader and longer. At the same time that all this is going on, the anterior extremity of the corpus callosum is extending forwards, always of course lying in the lamina terminalis, which is continually being "stretched." Corresponding to the cephalic bend of the



FIG. 14.—Scheme of commissures in higher mammal.

hemisphere, the corpus callosum develops its *genu* (fig. 14, *g*), which increases in extent in the higher mammalia, until in man it completely shuts off the "cavum septi" from the surface.

In macrosmatic mammals the exact morphogenesis of this region varies with the extent of the thickening of the lamina terminalis, which may more or less completely fill up the "splenial" recess. It is to be noted in many macrosmatic mammals (*e.g.*, the sloth and sheep) that the "stretching" of the lamina terminalis affects mainly those parts immediately in relation to the corpus callosum, while the ventral part in relation to the anterior commissure remains thick.

Whether the precommissural area takes any share in the formation of the septum pellucidum is very doubtful. In the higher mammals this region, which constitutes the gyrus subcallosus of Zuckerkandl, becomes very much reduced, and it would appear that the septum is developed solely from the lamina terminalis.

In the non-placental mammal the fascia dentata (figs 1, 9, and 10, *f.d*) and hippocampus lie immediately upon the dorsal aspect of the upper limb of the fornix commissure. In the placental mammal as the corpus callosum extends, it pushes the repre-

sentative of the hippocampal formation before it (fig. 11, *g.c.*). The atrophic hippocampal region which is thus pushed upwards and forwards, forms the "*gyrus supracallosalis*" and "*gyrus geniculi*" of Zuckerkandl. Posteriorly, the supracallosal gyrus appears to become continuous with the fascia dentata (figs. 15

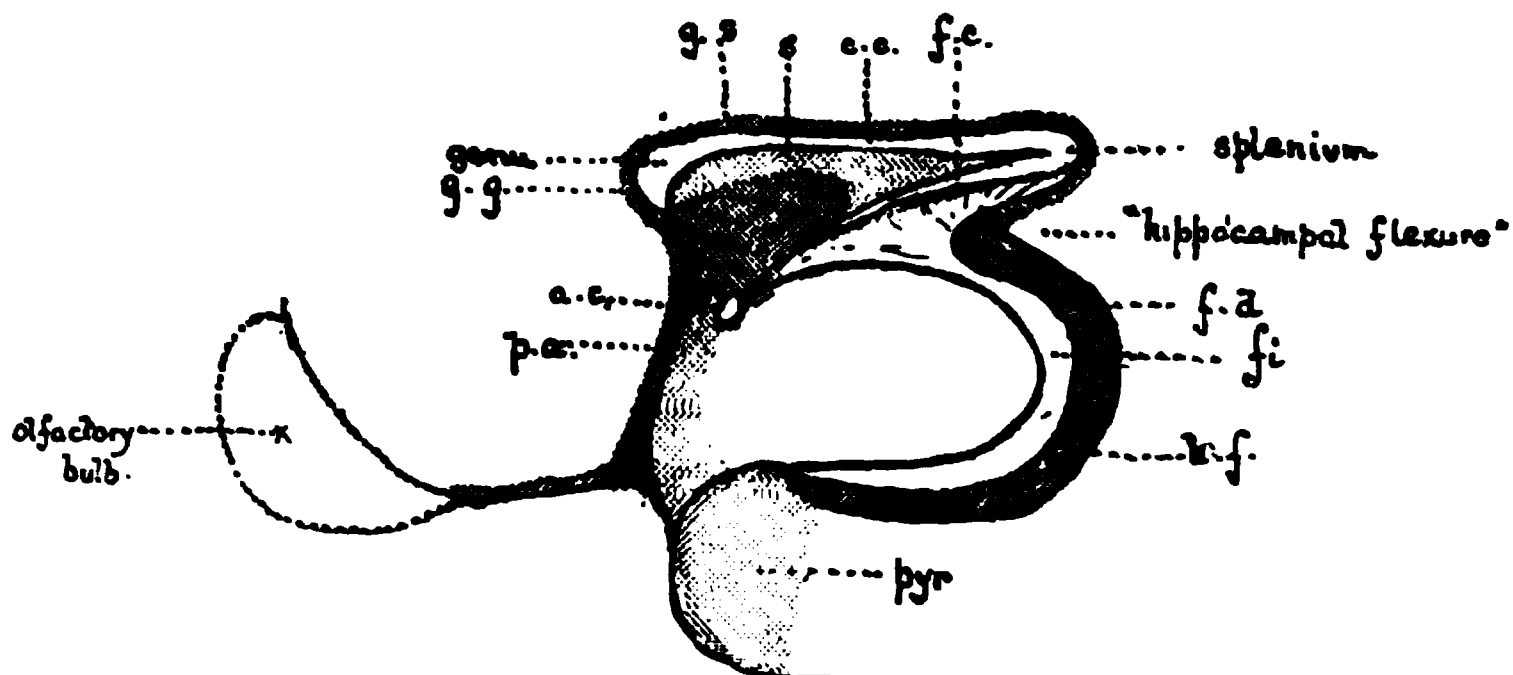


FIG. 15.—Limbic lobe of dog seen mesially.

and 17); but since the whole hippocampus (as met with in the Metatheria) disappears, the gyrus supracallosalis must be considered as the homologue of the dorsal part of the entire hippocampal formation, and not only of the fascia dentata.

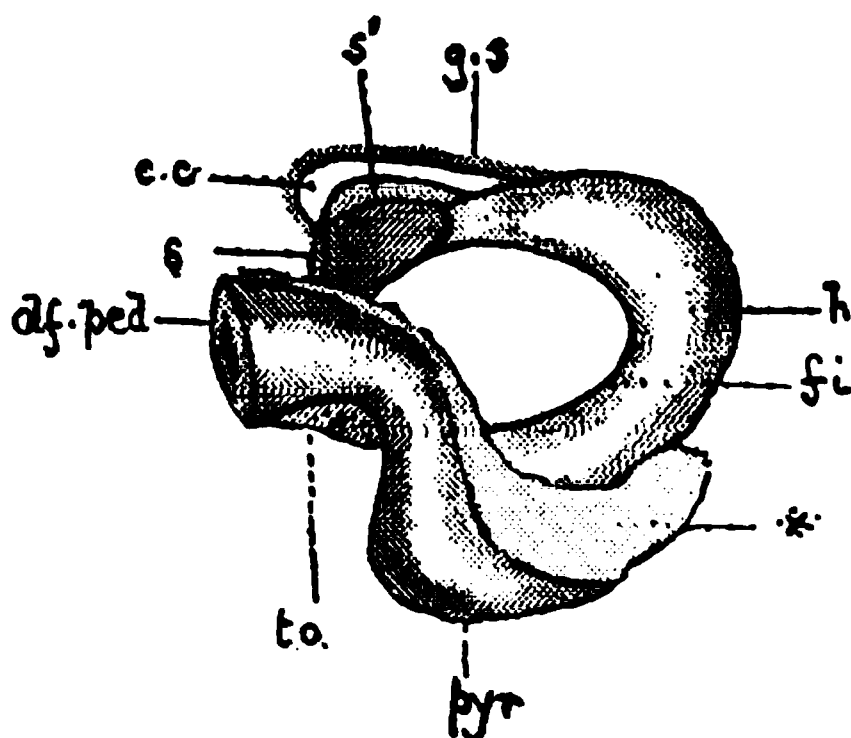


FIG. 16.—Limbic lobe of dog seen laterally.

The corpus callosum, in its backward growth, indents and pushes back the hippocampal formation, producing the characteristic bend (figs. 5, 15, and 17) which is found in all Eutherian

cerebra. The earliest stage of this indentation may be seen in *Dasypus* (fig. 11), and the more extensive bend is well demonstrated in the rabbit (fig. 13), and dog (figs. 5 and 15). It is especially well marked in the sheep, and may be clearly demonstrated in almost any placental mammal. Yet Hill would have us believe that the fascia dentata is *subcallosal*, and has no connection with the strizæ Lancisii at all. In an earlier paper I attempted to explain this bending of the hippocampus as a later development only found in macrosmatic mammals. As the result of fuller investigation, I find, however, that this is not so,

c.c

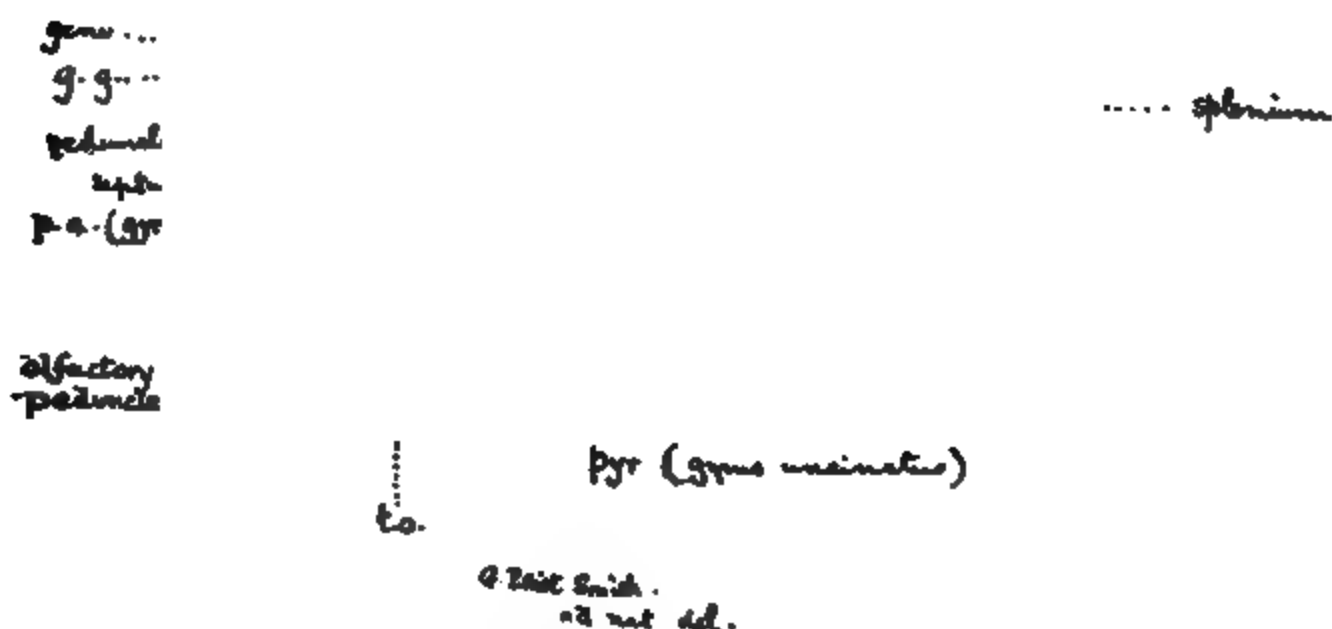


FIG. 17.—Commissures of human cerebrum.

for the condition is fairly constant in microsmatic as well as in macrosmatic Eutherian brains, and has a distinctly causal relation to the development of the corpus callosum. In macrosmatic, however, the full degree of bending is maintained to a greater extent than in microsmatic mammals. It is just possible, however, that the further extension of the corpus callosum in the latter (fig. 18) may tend to stretch and straighten the hippocampal region.

The relation of the corpus callosum to the gyrus supracallosalis and g. geniculi—which undoubtedly represent fascia dentata

—clearly shows that in its dorsal extension the corpus callosum could not have developed in a fusion of the hemisphere wall, as Mihalkovics and Martin would have us believe, but must, on the other hand, have developed in the structure which is immediately ventral to the representative of the fascia dentata. An examination of the marsupial brain (fig. 9) shows us that the structure immediately ventral to the fascia dentata is the thickened lamina terminalis. In front of the lamina terminalis in the Proto- and Meta-theria one finds the precommissural area. In the Eutherian brain one can recognise the homologue of this structure in the gyrus subcallosus, lying in front of the septum pellucidum (figs. 15 and 17, *p.a.*). It is evident, therefore, that if the septum pellucidum is derived from any other structure than lamina terminalis it must be from precommissural area. It has already been shown that these two regions—precommissural area and lamina terminalis—are simply different parts of one morphologically uniform plate. So that it does not signify much if part of the “septum” is derived from the precommissural area; nor does it detract from the value of the broad generalisation—that IN ALL VERTEBRATES THE WHOLE CEREBRAL COMMISSURAL SYSTEM DEVELOPS IN AND MORPHOLOGICALLY BELONGS TO THE LAMINA TERMINALIS.

The dorsal limb of the limbic lobe in Eutheria.

One is now in a position to examine the dorsal limb of the marginal ring in the placental mammal. A dissection of this region in the dog is represented in fig. 5, and it will be seen that, as in the metatherian brain (fig. 4, p. 162), the primitively *dorsal* limb is now not only dorsal but also *posterior* and *partly inferior*. It will be noticed, moreover, that the whole of the dorsal part of the “limb”—just that part of the lobe which indicates the true morphological position of the hippocampus (*vide* fig. 2)—has undergone an atrophic change to form the supracallosal gyrus (*g.s.*) and gyrus geniculi (*g.g.*). This corresponds to the position of the corpus callosum. The bend of the hippocampus underneath the *splenium* of the corpus callosum is clearly shown in fig. 5.

When the corpus callosum first indents the hippocampus in its backward growth (*vide Dasypus* or the figures of Martin and Marchand), only a relatively small part of the hippocampus lies above the commissure. It is evident that with the growth of the latter this segment of the hippocampus must become enormously stretched. This may possibly be one of the factors in the retrogression of the hippocampus in the Eutheria. For with the diminished importance of the sense of smell, the proportions of the hippocampus tend to decrease and not increase, as they would if they still formed the whole margin of the fissura choroidea.

Other parts of the "limbic lobe" in Eutheria.

The pyriform or "ventral limb" undergoes in placental mammals a bending exactly corresponding to that which occurs in the marsupial brain. This bend is represented in the dog's brain in fig. 16.

The anterior part of the pyriform lobe in higher mammals becomes very much reduced, and in man is represented merely by a narrow white band, which forms the lateral boundary of the anterior perforated spot, and which is generally distinguished as "*radix lateralis*."

It is instructive now to compare in a tabulated form the representatives in the human brain of the three simple segments of the limbic lobe in *Platypus*.

<i>Ornithorhynchus.</i>	<i>Homo.</i>
I. <i>Dorsal limb of limbic lobe</i> = hippocampus fascia dentata. fimbria.	gyrus geniculi. gyrus supracallosalis (striae Lancisii). fascia dentata. hippocampus. fimbria. fornix longus.
II. <i>Ventral limb of limbic lobe</i> = pyriform lobe.	gyrus uncinatus (excluding the subiculum cornu Ammonis). radix lateralis (bulbi olfactorii), the floor of the vallecule Sylvii joining the latter to the gyrus uncinatus.

*Ornithorhynchus.**Homo.*

III. "Pars intermedia" = thickened lamina terminalis ("commis-
sure-bed").
precommissural area.
tuberculum olfactorium.

septum pellucidum.
gyrus subcallosus.
gyrus infracallosus (*vel* fornicis).
locus perforatus anticus.

The Fornix.

It must be evident that the facts adduced in the above discussion must have an important bearing upon the interpretation of the fornix system, our ignorance of which has been so clearly exposed by the critical and exhaustive monograph of Honegger. In the marsupial, fibres derived from the alveus of the hippocampus converge towards the "septum," those coming from the descending limb forming the fimbria. Although the fibres which come from the anterior or dorsal limb of the hippocampus do not form a "fimbria," it will be convenient to speak of them as the "*anterior fimbria*," in contradistinction to the true or "*posterior*" fimbria.

The fibres from the extreme anterior end of the hippocampus proceed to their several destinations directly, and therefore afford an important key, which enables one to more clearly interpret the arrangement of the rest of the fornix system.

The fibres from the posterior or descending part of the hippocampus reach the posterior and inferior part of the "septum" by means of the posterior fimbria. Here a large proportion of the fibres crosses the mesial plane and forms the ventral limb of the fornix commissure (fig. 9). The non crossing fibres proceed forwards in the "septum" after passing between the fibres of the fornix commissure, and immediately divide into two series, which descend respectively in front of and behind the anterior commissure. The latter form part of the *columna fornicis* (figs. 8, 9, and 10, *c.f.*), and need not be further considered here. The *precommissural fibres* [Huxley], after passing through the "septum," arch down in the precommissural area to the base of the brain.

The fibres of the "anterior fimbria" have a corresponding arrangement. In the most dorsal part of the "septum," *i.e.*,

immediately below the fascia dentata (fig. 9), the commissural fibres cross the middle line (*f.c'*). The uncrossed fibres, after passing between the commissural fibres, enter the septum and behave exactly like those from the "posterior fimbria," *i.e.*, divide into *pre-* and *post-commissural columns*.

The precommissural fibres of Huxley, which include the "Riechbündel des Cornu Ammonis" of Zuckerkandl, include a number of strands of varied significance. An important series of fibres arises from cells in the tuberculum olfactorium and precommissural area, and after passing through the latter and the "septum" they enter the various alveus regions. They constitute a path from the bulbus olfactorii to the hippocampus.

Another series arches backwards below the anterior commissure and connects the hippocampus with the basal part of the "tween-brain," and possibly with the pyriform lobe. This, however, is not certain. In the *Anatomischer Anzeiger* of March 1895, I described a bundle of fibres which arose in the olfactory bulb, and, after passing through the precommissural area, either directly entered the anterior extremity of the fascia dentata to terminate in its molecular layer, or else entered the anterior fimbria to end in a similar manner further back.

Following the analogy of Zuckerkandl's nomenclature, I called this track of fibres "*the olfactory bundle of the fascia dentata*." In the anterior fimbria it extends backwards at the ventral margin of the fascia dentata, *i.e.*, between the latter and the dorsal limb of the fornix commissure, and distributes fibres into the whole extent of the fascia dentata.

What happens in the placental mammal? The anterior limb of the hippocampus and its commissure disappear, and the corpus callosum takes its place. The posterior or descending limb of the hippocampus, with its crossed and uncrossed fibres, is left, and maintains the arrangement which I have just described in the marsupial. The precommissural fibres, coursing through the septum, in part form the "*fasciculus arcuatus septi pellucidi*" of Ganser, the "*fornix longus*" of Forel, which consequently contains *no* crossing fibres, as von Koelliker has already stated in opposition to Honegger. Numbers of non-crossing fibres from the hippocampus, in the region of the splenium, pass through the fornix

commissure, splenium, and body of the fornix to enter the septum pellucidum, just as they pass through the fornix commissure in the non-placental mammal. These fibres, which Ganser, Koelliker, Beevor, and Vogt have described (but whose presence Honegger and Meyer have denied), are readily seen in the human brain, and join the so-called fornix longus.

The "olfactory bundle of the fascia dentata" maintains a similar course to that which it follows in the monotreme. It passes through the gyri subcallosus, geniculi, and supracallosalis, forming one of the constituents of the stria longitudinalis medialis, lying above the corpus callosum, just as it lies above the fornix commissure in *Ornithorhynchus*. Posteriorly it enters the fascia dentata to terminate there.

Other fibres belonging to the precommissural system pass through the septum pellucidum and perforate the corpus callosum to join the striæ of Lancisius.

Portions of the fibre tract, known as the cingulum, also belong to the fornix system, but their exact homologies are doubtful.

It would appear, therefore, that the fibres of the fornix longus are serially homologous with the other longitudinal uncrossed fibres of the fornix system, and behave in a similar manner, dividing into pre-commissural and post-commissural bundles.

The relation of the callosal gyrus and hippocampus major to the limbic lobe.

Broca and, following him, most anatomists include the *gyrus callosalis* or *fornicatus* in the limbic lobe. It is evident from what has been said above that it is not marginal or "limbic" in the sense of Broca, Foville, and Gerdy, since it is separated from the hilum by the hippocampus or its representative—the *gyrus supracallosalis*.

Does it form part of the olfactory centre? It is not directly connected with the olfactory apparatus like all the parts of the "true limbic lobe" or "rhinencephalon" of Turner. Although strongly associated with the undoubted olfactory centre, it has no more right to be considered part of that "centre" than any other part of the pallium.

Phylogenetically it is of much more recent origin than all the

parts of the true limbic lobe, so that it does not fulfil Broca's third criterion.

The question of the homology of the so-called "limbic fissure" does not rest upon any sure scientific basis. A mere resemblance between parts in a series of cerebra is not sufficient ground for concluding that they are homologous, in the absence of any corroborative evidence to support the thesis.

In a communication made to the International Medical Congress in Rome in 1894, Debierre suggested that the term limbic lobe be applied to the fascia dentata and striæ Lancisii.

There can be no question of the propriety of including the pyriform in a limbic lobe, because it is marginal; the external olfactory terminates in it; and it is phylogenetically old.

Although the hippocampus (as distinct from the fascia dentata) is not marginal, and probably has other functions in addition to those connected with the olfactory sense, still it is so closely connected with the olfactory apparatus, and especially with the fascia dentata, that the two structures may be regarded as one formation, which is marginal and mainly olfactory.

Rudolph Burckhardt has shown that the oldest parts of the brain tube are found in the mesial plane. They are "conservative" and maintain their essential morphology unchanged, while the plastic lateral regions are constantly changing and undergo a progressive evolution. Similarly, in the cerebral hemisphere, the oldest regions are situated around the "hilum," and as new regions are "added" (Edinger), they appear on the periphery of the older regions, which hence become limbic. Thus the cerebral cortex of the Reptile becomes relegated in the mammal to the region immediately surrounding the hilum of the hemisphere, and constitutes the "true limbic lobe."

LITERATURE.

As this is merely a preliminary to a fuller paper, no attempt will be made to give a full list of the very voluminous literature relating to this subject, but only several papers which have a direct bearing upon the subject-matter will be quoted.

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CH. DEBIERRE. *Qu'est-ce que le lobe limbique?* From a synopsis of a paper read before the International Congress in Rome, 1894. *Arch. ital. de Biologie*. Tome xxi., Fasc. iii., p. 21.

EXPLANATION OF FIGURES.

Fig. 1. Mesial aspect of cerebral hemisphere of *Ornithorhynchus*. Nat. size. The limbic lobe is shaded. The greater part of the hippocampus (*h*) is hidden by a pallial operculum, only a small fusiform area of the fascia dentata (*f.d*) showing on the surface; but the extent of the hippocampal region is shaded. Page 159.

Fig. 2. Figure showing shape of hippocampus of *Ornithorhynchus*. Nat. size. Drawn from a dissection which exposed the ventricular aspect of the hippocampus. Figs. 2–5, page 162.

Fig. 3. Hippocampus of *Echidna*. Nat. size. Drawn from a specimen prepared in same way.

Fig. 4. Hippocampus of marsupial (*Dasyurus viverrinus*). Nat. size. Prepared in same way as figs. 2 and 3.

Fig. 5. Hippocampus of dog. Nat. size. Drawn from a dissected specimen represented in figs. 15 and 16.

Fig. 6. Scheme of sagittal section of lamina terminalis of reptile, page 189.

Fig. 7. Ditto of bird. Figs. 7-12, page 189.

Fig. 8. Ditto. *Ornithorhynchus*. Drawn from a Weigert-stained sagittal section through the mesial hemisphere wall.

Fig. 9. Ditto. *Perameles nasuta*. Drawn from a sagittal section stained by the Weigert-Pal method.

Fig. 10. Scheme of commissures in a higher marsupial. Modified from a *Macropus* brain.

Fig. 11. Scheme of arrangement of commissures in *Dasypus sexcinctus*. Modified after Sir William Turner.

Fig. 12. Ditto. Sloth after Sir W. H. Flower.

Fig. 13. Scheme of commissures in rabbit, page 193.

Fig. 14. Scheme of commissures in a higher placental mammal, page 195.

Fig. 15. The limbic lobe of a dog, seen from the mesial aspect. Nat. size, page 196.

Fig. 16. Drawing of a dissection of the cerebrum of a dog, in which all the hemisphere except the true limbic lobe was removed. Viewed from the lateral aspect, showing the ventricular aspect of the hippocampus (*h*) and septum (*s*). The surface of the pyriform lobe is seen (*pyr*), and at *x* the cut surface where the pallium has been detached. Nat. size, page 196.

Fig. 17. Mesial aspect of the commissures of a human brain. Nat. size, page 197.

EXPLANATION OF LETTERING.

f.c. = fornix commissure.

a.c. = anterior commissure.

c.c. = corpus callosum.

s. = septum pellucidum.

h. = hippocampus.

f.d. = fascia dentata.

fi. = fimbria.

c.f. = columna fornicis.

g.c. } = gyrus supracallosus.
g.s. }

g.g. = gyrus geniculi.

h.f. = hippocampal fissure.

p.a. = "precommissural area" of the median cortex.

t.o. = tuberculum olfactorium.

pyr. = pyriform lobe.

c.s. = cavum septi pellucidi.

SYDNEY, N.S.W., August 2, 1895.

AN INTERESTING ABNORMALITY OF THE HEPATIC ARTERY, WITH EXPLANATION OF THE CONDITION. By Professor EDWARD FAWCETT, *University College, Bristol.*

THE Hepatic Artery is so often abnormal in its mode of origin that some apology is needed in describing this specimen.

My excuse for this record is based on the supposition, that the history of an abnormality is not always so evident, and perchance so interesting.

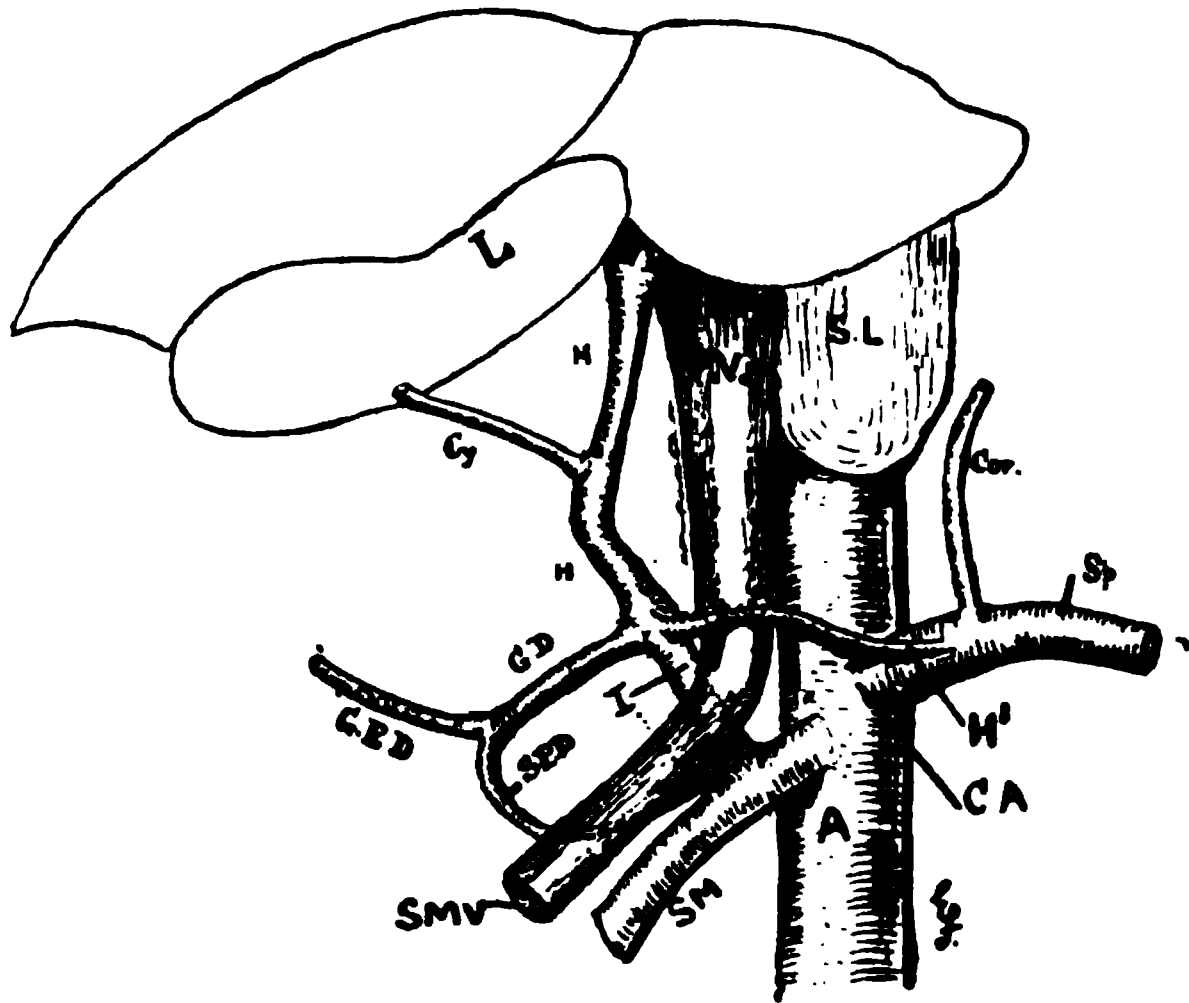


FIG. 1.—H', true hepatic artery; HH, continuation of hepatic artery to liver (L); GD, gastro-duodenal branch dividing into gastro-epiploica dextra (GED) and superior pancreatico-duodenal (SPD); Cy, cystic artery; I, functional hepatic artery, is it inferior pancreatico-duodenal? or is that to which dotted line is directed? CA, coeliac axis; Cor, coronary; Sp, splenic; A, aorta; SM, superior mesenteric; PV, portal vein; SMV, superior mesenteric vein; SL, Spigelian lobe of liver.

In this case my attention was first attracted by an arterial circle which was formed around the portal vein, a circle which was made up of the following vessels: in front, a small vessel (fig. 1, H') which sprang from the coeliac axis, and apparently ended by anastomosing with a large branch of the superior

mesenteric artery (fig. 1, SM), which went up to the liver and appeared to be an abnormal hepatic artery, as indeed it was functionally, but not developmentally. This branch of the superior mesenteric formed the right segment of the circle. The left segment was formed by three vessels,—from below upwards,—the trunk of the superior mesenteric (SM), the abdominal aorta (A), and the coeliac axis (CA). Perhaps the term arterial triangle would have been more applicable than arterial circle, though the latter term is one more commonly used.

The accompanying figure will show this more clearly. At first sight I was inclined to dismiss the whole thing as being simply another instance of a hepatic artery arising from the superior mesenteric; but this small cross branch between the coeliac axis and what appeared to be a hepatic branch of the superior mesenteric, and the circle or triangle it completed with the others around the portal vein, caused me to make further investigation into this primarily apparently simple condition, with the result that a really interesting state of affairs was disclosed. It is evident that this small cross branch (fig. 1, H') is really the normal hepatic artery, which has blended with the superior pancreatico-duodenal (I) artery at some time, and from some cause which I don't venture to explain. It is also evident that the blood, having now found a more direct route than by the usual course, has caused the inferior pancreatico-duodenal artery to dilate, and the true hepatic artery to shrink. The arterial system, beyond the point of junction of the inferior pancreatico artery with the true hepatic (H'), is evidently that normally developed in connection with the hepatic artery. Thus we see, coming off at the junction of the true hepatic artery with the apparent one (the enlarged inferior pancreatico-duodenal), the gastro-duodenal artery (GD), which after a course of about an inch, divides into the gastro-epiploica dextra (GED), and the superior pancreatico-duodenal (SPD). This last vessel, as will be seen in the diagram, was small, and, after passing behind the superior mesenteric vein (SMV), ended by anastomosing with the inferior pancreatico-duodenal, near its origin from the superior mesenteric. The large vessel (HH) going to the liver beyond the junction of the true hepatic artery with the

inferior pancreatico-duodenal, is evidently the continuation of the true hepatic artery although it appears to be the continuation of the inferior pancreatico-duodenal, and no doubt it functionally is in the main. It is seen to give off a cystic branch to the right, when nearing the liver, in much the usual manner.

That this small cross branch is the true hepatic artery I have no doubt; firstly, because it arises from the coeliac axis, and secondly, because it passes in front of the portal vein. For the second reason, it is certain that that part of the artery (fig. 1, HH) passing from the junction with the cross branch to the liver, is the modified continuation of that cross branch; in other words, is the continuation of the true hepatic. The part below the junction of the cross branch (fig. 1, I) undoubtedly is not a true hepatic, because it lies on a different plane from the normal one, being placed behind the superior mesenteric vein.

Of the nature of the branch that I have chosen to speak of as the inferior pancreatico-duodenal I am not so certain. It can, however, I think, only be one of two things: it is either the inferior pancreatico-duodenal artery, or an enlarged branch of it which has joined with some pancreatic branch of the gastroduodenal.

The pyloric branch of the hepatic artery is not represented, as it was cut away in the removal of the stomach before I made my observations.

I must thank two of my students, Messrs Frost and Hemsted, for the readiness with which they gave their help. Had their dissection not been executed with great care, I should not have noticed this interesting condition.

Lastly, I venture to think that it is not unlikely that many of the apparent origins of the hepatic artery from the superior mesenteric may possibly have a similar explanation.

ABNORMAL DISTRIBUTION OF THE NERVUS
DORSALIS SCAPULÆ, AND OF CERTAIN OF THE
INTERCOSTAL NERVES. By A. FRANCIS DIXON, M.B.,
Chief Demonstrator of Anatomy, Trinity College, Dublin.

IN a female subject dissected in the School of Anatomy, Trinity College, Dublin, the following abnormalities were observed in the nerve to the Rhomboid muscles (nervus dorsalis scapulæ) on the left side, and in certain of the intercostal nerves of both sides. The nerve to the Rhomboids on the left side not only supplied these muscles, together with the levator anguli scapulæ, but it also sent a branch to supply a small area of skin close to the mesial line at the level of the fifth and sixth dorsal spines. This branch, to reach the area of its distribution, pierced the trapezius muscle a little below the lower border of the rhomboideus major muscle. The nerve was easily traced through the trapezius, and no filaments passed to the fibres of that muscle. Unfortunately, no opportunity was obtained to examine whether this cutaneous branch of the nerve to the rhomboids was also present on the right side. The intercostal nerves, which in the same subject presented abnormalities, were the second, third, and fourth of both sides. In each of these nerves, at the point where normally the lateral cutaneous nerve is given off, a large branch was present. This branch, however, not only divided into the normal anterior and posterior divisions, but also sent a long slender branch forwards towards the middle line, which, from its distribution, evidently represented the anterior cutaneous branch of the intercostal nerve. These slender branches lay in each case superficial to the fascia, curving the external intercostal muscle and anterior intercostal aponeurosis, and those corresponding to the third and fourth intercostal nerves pierced the origin of the pectoralis minor muscle from the anterior intercostal aponeurosis. No branches were given off by these nerves until, reaching nearly to the sternum, they turned forwards, and, piercing the pectoralis major muscle, supplied the skin in this region. The course presented

by these nerves was peculiar, and was similar in each case. In the first instance each nerve passed downwards to the upper margin of the rib bounding the intercostal space below, along which it turned forwards. As it approached the junction of rib and cartilage, however, the nerve turned upwards, till it reached the lower border of the costal cartilage above, along the lower margin of which it was continued until the sternum was reached. Some of the terminal filaments of the nerve corresponding to the second intercostal space passed upwards over the second costal cartilage, and supplied also part of the skin over the first intercostal space. In each of the intercostal spaces, when these abnormal anterior cutaneous nerves were present, no other representative of an anterior cutaneous branch was found, although carefully looked for; but the whole intercostal nerve, after the large lateral branch was given off, was distributed to the muscles of the thoracic wall. We may therefore assume that, in the case of the second, third, and fourth intercostal nerves on both sides of this subject, all the cutaneous fibres were given off in a common trunk at the lateral line of the body.

I have been unable to find any description of such abnormal distribution of the nervus dorsalis scapulæ, or of the intercostal nerves, in the text-books of Schwalbe, Krause, or Quain.

ABNORMAL ANTERIOR ABDOMINAL VEIN IN A
FROG. By A. H. R. BULLER, Zoological Laboratory,
Mason College, Birmingham.

WHILE dissecting a Frog, I had the good fortune to meet with a striking deviation from the normal with regard to a part of the vascular system. As I have been unable to find any references to a similar case, it would seem that the abnormality, if not now observed for the first time, is of very rare occurrence. In its possible bearing on Amphibian ancestors, it seems to me to be of sufficient interest and importance to merit a brief description. The Frog in question, obtained last May, was apparently almost adult, measuring from snout to anus $2\frac{1}{4}$ inches, and in sex was a female with small ovaries.

The anterior abdominal vein had its origin from the pelvic veins in the usual way, and from thence extended in its normal position in the medio-ventral line of the abdominal wall as far as the liver. Here, instead of joining the hepatico-portal vein, it curved to the right, and poured its blood into the right superior vena cava at the point where that vein was formed, in the usual fashion, by the union of the external jugular, the innominate, and the subclavian veins. There was, however, a branch passing from the anterior abdominal vein to the liver, but this was quite small compared with the large vein which joined the right superior vena cava in the way described above.

The explanation of this singular abnormality must be looked for in the embryonic development of the anterior abdominal vein. Marshall, in his *Vertebrate Embryology* (p. 184), gives the following account of the origin of the vein, which I venture to quote *in extenso*:—"The anterior abdominal vein is at first paired, and is in connection, not with the liver, but the heart. The pair of vessels appear first in the ventral body wall, extending backwards a short distance from the sinus venosus; they soon extend further backwards, and acquire communications with the veins of the hind legs and of the bladder. At a later stage the two anterior abdominal veins unite at their hinder ends, in

front of the bladder, while further forwards the vein of the *right* side *disappears*, the *left* one alone *persisting*.¹ Later still, the anterior abdominal vein loses its direct communication with the sinus venosus, and acquires a secondary one with the hepatico-portal veins, or afferent veins of the liver." It may be added that the account given by Marshall in the case of the common Frog (*Rana temporaria*) is practically identical with that given by Goette for *Bombinator igneus* (*Entwick. der Unke*, pp. 765, 766).

The obvious explanation of the abnormal vein in my Frog is, that while the posterior portions of the two embryonic anterior abdominal veins have united to form the adult mesial trunk, and the anterior or cardiac portion of the left vein has atrophied, the right has retained its embryonic connection with the sinus venosus, through its union with the superior vena cava of the right side.

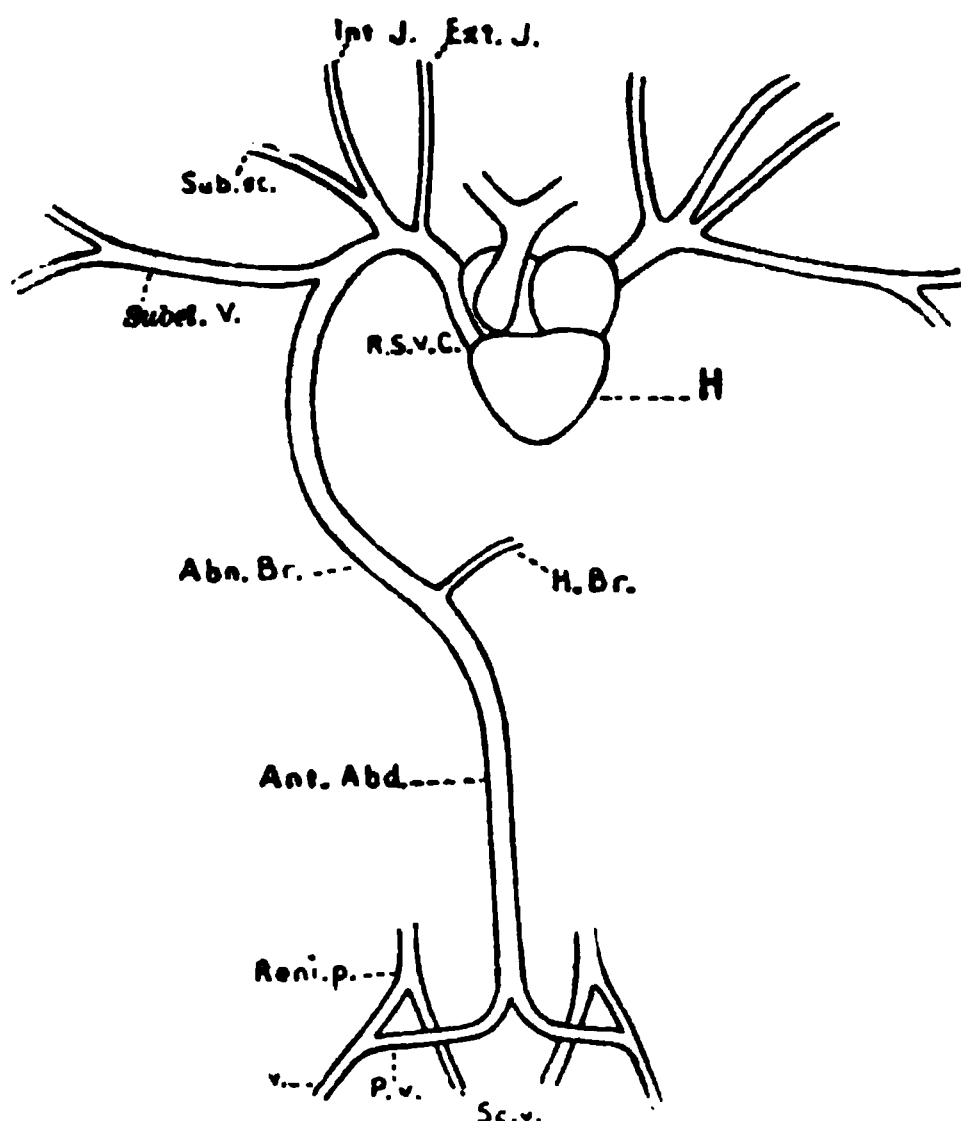
It is interesting to compare the abdominal vein of my Frog with that of the Australian Dipnoid, *Ceratodus fosteri*. According to Baldwin Spencer,² there exists in this fish "veins which may in all probability be rightly regarded as forming an anterior abdominal system comparable to that obtaining in Amphibia; though at the same time there are considerable differences between the two" (*l.c.*, p. 20). He describes a mesial anterior abdominal vein, formed posteriorly by the union of two pelvic veins, and continued forwards in the median line of the abdominal wall towards the heart. On approaching that organ the vein curves to the right, and opens into the right side of the sinus venosus, close to the junction of the right superior vena cava with that cavity. It is obvious, therefore, that the abnormal vein in the Frog is essentially similar to the normal anterior abdominal vein of the Dipnoid. In fact, the only point in which the Frog differs from *Ceratodus* is, that in the latter no secondary connection with the liver exists, or, at all events, has not yet been discovered, whereas, in the former, such a connection by means of a hepatic branch is present. Consequently in this respect the Frog represents a stage in advance

¹ The *italics* are mine.

² *Contributions to our Knowledge of Ceratodus*. Part I.—The Blood Vessels. (Macleay Memorial Volume.)

of *Ceratodus*. We are entitled, therefore, I think, to conclude that, with regard to the anterior abdominal vein of the Frog, we have here a case of reversion to an ancestral stage, slightly in advance of that reached by *Ceratodus*, and therefore a case which, from its transitional character, tends to some extent to bridge over the gap between the Dipnoid and the normal Amphibia.

There is, however, one feature which still remains unexplained. In the abnormal Frog the *right* anterior abnormal vein has *persisted*, while in the ordinary course of embryological development of *Rana*, the right always disappears before the left. If we interpret these embryological facts in the light of the Recapitulation Theory, we might venture to do so in this way. The primitive ancestors of the Frog originally had two



distinct anterior abdominal veins. In the course of evolution these veins gradually united behind so as to form a mesial vein, remaining, however, distinct in front, where they were connected with the sinus venosus. Later on, the right vein gradually disappeared while the left persisted. Later still, the remaining left anterior abdominal vein gradually developed a secondary

connection with the liver and the hepatico-portal circulation. This connection was gradually enlarged at the expense of the direct connection of the vein with the heart, until at last the latter atrophied altogether, the final stage being represented by the normal anterior abdominal vein of existing Frogs. It will therefore be seen that at no time, according to the Recapitulation Theory, was there a stage in the evolution of the system of the anterior abdominal veins in which the right vein persisted without the left. On this point the abnormal case seems to be at variance with this theory as ordinarily understood.

In all other features the Frog appeared to be perfectly normal. The diagram, p. 213, represents a ventral view showing that part of the venous system to which reference has been made. I have endeavoured to make the relative size of the normal to the abnormal portions of the anterior abdominal vein as accurate as possible.

REFERENCE LETTERS.

- H.* Heart.
- Ant. Ab.* Anterior abdominal vein.
- Abn. Br.* Persistent abnormal connection of the anterior abdominal vein with the right superior vena cava.
- H. Br.* Hepatic branch.
- R. S. V. C.* Right superior vena cava.
- Subcl. v.* Subclavian vein.
- Subsc.* Subscapular vein.
- Ext. J.* External jugular vein.
- Int. J.* Internal jugular vein.
- P. v.* Pelvic vein.
- F. v.* Femoral vein.
- Sc. v.* Sciatic vein.
- Renip.* Reniportal vein.

THE BILE-SALTS (GLYCO- AND TAURO-CHOLATE OF SODA) IN THEIR RELATION TO THE SECRETION OF UREA, &c. By G. H. EDINGTON, M.B. Glasgow. (PLATE VI.)¹

THE following observations are the result of a research undertaken at the suggestion of Dr W. J. Fleming, Surgeon to the Glasgow Royal Infirmary, from a patient in whose wards the material was obtained.

The investigation was carried out in the Physiological Laboratory of the University of Glasgow, by the kind permission of Professor M'Kendrick, and was determined on in view of the small number of observations made during life on the composition of human bile.

It was hoped to have made analyses over an extended period; but from various causes—partly the delay in taking up the inquiry, and also the patient's anxiety to have the fistula closed—these did not exceed thirty in number. Even with this limited evidence, there seems to be shown, what was made the chief point in the inquiry, viz.:—a relation between the excretion of the Salts of the Bile-acids (Glycocholate and Taurocholate of Soda) and that of Urea.

I wish here to express my sincere thanks to Dr Fleming for the opportunities placed at my disposal in his wards, and for the assistance he so freely rendered me in every way; and I have also to thank Professor M'Kendrick for his kind permission to work in the Physiological Laboratory, and for the many practical hints he gave me while conducting the experiments.

This paper is arranged under the following headings:—

I. Narrative of Case. II. Limitation of the Inquiry. III. Methods. IV. Detailed Statement. V. General Conclusions. VI. Comparison with other Observers. Charts, and Tabular Statement. VII. References.

¹ This paper was presented to the University of Glasgow as a Thesis for the degree of M.D.

I. Narrative of the Case.

Mrs M'C——, æt. 53, Housewife, admitted to the Glasgow Royal Infirmary on the 26th April 1895, complaining of very severe pain in the right hypochondriac region, of 2 days' duration. She had experienced for many years back very poor appetite, but, so far as could be ascertained, had never had at any time anything of the nature of dyspepsia. She was habitually constipated, but had otherwise enjoyed good health.

Two days before admission she awoke at 3 A.M. with a severe pain in the right hypochondriac region. This was accompanied by vomiting of "bilious" material. Poultices were applied over seat of pain, but without avail, and she was sent into hospital. On admission she stated that her bowels had not moved for three days previously, although no fewer than ten enemata had been administered during that time. On admission, there was great pain complained of in right hypochondrium, the skin over which had been reddened by poulticing; after admission she had occasional bilious vomiting. A distinct tumour could be felt in the line of the gall-bladder, but somewhat lower down than usual.

The abdomen was opened in the right linea semilunaris, and a freely-movable sausage-shaped tumour, resembling a kidney, was pulled into the wound and fixed with a suture. A quantity of mucus-like fluid was drawn off from it by a trocar, after which the tumour was found to consist of a collection of stones in the sac of the gall-bladder. The bowel, on being examined, was not found to contain any of these concretions. After completing the suture of the bladder to the wound, a dressing was applied. Two days later, the sac was freely opened by incision, the gall-stones extracted, and a drainage-tube inserted through the opening. On the day following, there was a copious discharge of bile from the wound, while a large fæcal evacuation followed the administration of an enema of soap and water, castor oil and turpentine.

As regards the progress of the case, the woman continued in good health; no jaundice noted at any time; temperature normal; appetite somewhat poor and bowels constipated, requir-

ing exhibition of medicine regularly. It was necessary to change the dressings on the fistula frequently, on account of their being saturated with discharge of bile. The fæces, however, were always normally coloured, although somewhat offensive. On one occasion the fistula was tightly plugged with gauze, and this was left in for twenty-four hours at least, without any accumulation of bile having taken place in the gall-bladder.

The patency of the ducts having been established beyond doubt, it was decided to close the fistula. This was done by inverting the raw edges of gall-bladder and stitching the freshened skin-margin over that viscus. The wound healed by first intention and the patient went out well. A month or so later she reported herself as having kept well since dismissal.

II. *Limitation of the Inquiry.*

Towards the end of May, Dr Fleming suggested to me the advisability of utilising the opportunity thus presented of analysing fresh human bile, and on the 6th of June the collecting of the discharge from the fistula was commenced. It was at first intended to make a complete analysis of the secretion, but it was found that this would involve more time than was available, and on talking the matter over with Professor M'Kendrick it was finally resolved to limit the inquiry to the determination of the bile-salts (Glycocholate and Taurocholate of Soda), the influence, if any, on the quantity secreted, of diet, time during the twenty-four hours, and temperature, and also as to any relation between the excretion of the salts and the amount of the urea excreted in the urine.

It was also determined to note the quantity of bile collected four-hourly, it being kept fully in mind, however, that there was a free vent into the intestine which would hinder any conclusions being drawn as to the *total* quantity excreted in the twenty-four hours.

III. *Methods.*

An attempt was made to collect the *bile* in the way described by Noël Paton ⁽¹⁾, by means of an india-rubber tube connected with a Woulf's bottle; but this not proving successful, a modification

was tried, by means of a balloon transfixed by the end of the tube, the former to be inflated when half way in the fistula, so as to assume an hour-glass shape. This was not found to be practicable, and finally the end of the tube was made bulbous by introducing a piece of glass tubing within its lumen. It was then passed into the fistula for a distance of three or four inches, and the tube retained in position by means of gauze strips dipped in collodion and made fast to skin of abdomen. Escape of bile alongside the tube was thus obviated. Silk threads were also used after the manner of shrouds in rigging. It was not found that the plugging action of the collodionised gauze was perfect, and it had to be renewed on several occasions.

The quantity collected was removed from the Woulf's bottle every four hours into a stoppered bottle. It was afterwards measured, and the estimation of the bile-salts made from sample from total daily (8 a.m.—8 p.m.) and total nightly (8 p.m.—8 a.m.) specimens. The physical appearances, colour, &c., of specimen were also noted. The reaction and specific gravity were taken irregularly, the latter being obtained by means of the common mercury-bulb urinometer.

The process adopted for the estimation of the bile-salts was as follows, and was taken from Sheridan Lea ⁽⁸⁾:—

A quantity of fresh bile, generally 25 c.c., was mixed with silver sand and evaporated on a sand-bath to a pulverisable mass. This was then extracted in a flask with strong boiling alcohol (rectified spirit), and the resulting green solution was filtered, decolorised with animal charcoal, and concentrated to a syrup. The syrup was then dissolved in a minimal quantity of absolute alcohol (if necessary, warmed), and precipitated with an excess of ether. The precipitate, consisting of glycocholate and taurocholate of soda, was collected on a weighed filter-paper, dried carefully, and weighed. No attempt was made to separate the one salt from the other.

The *Urine* was collected and measured (1) from 8 a.m.—8 p.m. and (2) from 8 p.m.—8 a.m. In each of these twelve-hourly quantities the specific gravity was observed and noted, and from a sample of total daily and total nightly quantity, estimation of urea was made by means of Gerrard's ureameter. The sex of the patient made it sometimes impracticable to obtain the whole

quantity of urine passed. In these cases the percentage was estimated, but of course no conclusion could be drawn as to the quantity of urea excreted.

An account of diet, &c., was kept by the nurses in attendance on the patient.

IV. Detailed Statement.

Note.—The “day” of 24 hours dates from 8 A.M. of the day preceding.

June 6th. Quantity of bile collected :—

8 a.m. -12 noon	17	c.c.-	8 p.m. -12 mdnt.	19	c.c.
12 noon - 4 p.m.	45	„	12 mdnt.- 4 a.m.	15	„
4 p.m. - 8 p.m.	26·5	„ —88·5 c.c.	4 a.m. - 8 a.m.	44	„ —78 c.c.
The colour throughout was greenish. Urine, 8 a.m.—8 p.m., 15 oz., sp. gr. 1014, pale yellow. From 8 p.m.—8 a.m., 6 oz., sp. gr. 1020.					

Diet.

8 a.m. cocoa, 9 oz., $\frac{3}{4}$ slice bread, fish.	8 p.m. soda water, 4 oz.
10.15 a.m. whisky, $\frac{1}{2}$ oz., water 3 oz.	9 p.m. whisky, 1 oz., water 3 oz.
1 p.m. soup, 12 oz., mince 4 oz.	4 a.m. cocoa 10 oz., $\frac{1}{4}$ slice bread and butter.
3 p.m. soda water, 4 oz.	6.30 a.m. whisky 1 oz., water 1 oz.
4 p.m. tea, 12 oz., 1 slice bread.	

She had at 2 a.m., castor oil, $\frac{1}{2}$ oz., and potass water, 1 oz.

The patient was very much excited about the proceedings, and complained of not having slept at all during the night. Castor oil was followed by a large motion consisting of dark-brown faecal masses in fluid, and having an evil odour.

June 7th. Quantity of Bile.

8 a.m. - 12 noon.	48	c.c.	Colour, greenish yellow.
12 noon - 4 p.m.	9	„	lighter.
4 p.m. - 8 p.m.	17	„	„
8 p.m. - 12 mdnt.	55	„	„
12 mdnt. - 4 a.m.	66	„	green and hazy.
4 a.m. - 8 a.m.	36·5	„	greenish yellow, clear.
<hr/>			
231·5 c.c.			

Urine.—8 a.m. - 8 p.m. 14 oz., sp. gr. 1024.

8 p.m. - 8 a.m. 12 oz., sp. gr. 1022.

26 oz.

Diet, ordinary.

June 8th. Quantity of Bile.

8 a.m. - 12 noon	22	c.c.	Colour, yellow, greenish tint	{	·0450 grm.
12 noon - 4 p.m.	38	„	paler yellow		Salts in 25 c.c.
4 p.m. - 8 p.m.	22	„	„		— ·1800 grm.
8 p.m. - 12 mdnt.	63	„	darker, greenish, hazy	{	·0161 grm.
12 mdnt. - 4 a.m.	18·5	„	lighter colour, hazy		Salts in 25 c.c.
4 a.m. - 8 a.m.	50	„	very dark green		·0644 grm.
<hr/>				per 100 c.c.	
213·5 c.c.					

Urine.—8 a.m. – 8 p.m. 18 oz. sp. gr. 1024 *Urea* 3·6 %
 8 p.m. – 8 a.m. 10 oz. sp. gr. 1025 „ 3·5

23 oz.

Diet, ordinary.

Patient says she now feels quite comfortable as regards tubing, &c.

		June 9th.	Quantity of Bile.		
8 a.m.	– 12 noon	49	c.c.	faint greenish tint	{ .0412 grm. Salts in 25 c.c. = .1648 grm. per 100 c.c.
12 noon	– 4 p.m.	42	„	„	
4 p.m.	– 8 p.m.	49	„	very faint green	
8 p.m.	– 12 mdnt.	45·5	„	golden yellow	{ .0750 grm. Salts in 25 c.c. = .3000 grm. per 100 c.c.
12 mdnt.	– 4 a.m.	42	„	darker „ mucus	
4 a.m.	– 8 a.m.	43·75	„	still darker, mucus	
		<hr/> 271·25 c.c.			

Urine.—8 a.m. – 8 p.m. 9 oz. sp. gr. 1030 clear yellow, deposit of urates *Urea* 2·8 %
 8 p.m. – 8 a.m. 8 oz. sp. gr. 1015 „ mucous sediment „ 1·6

Diet, ordinary.

		June 10th.	Quantity of Bile.		
8 a.m.	- 12 noon	51.5 c.c.	yellow, greenish tint	{	.1216 grm.
12 noon	- 4 p.m.	51 „	lighter		Salts in 50 c.c.
4 p.m.	- 8 p.m.	65 „	greenish and opaque		= .2432 grm.
					per 100 c.c.
8 p.m.	- 12 mdnt.	55 „	yellowish green	{	.1792 grm.
12 mdnt.	- 4 a.m.	20.5 „	light yellow		Salts in 50 c.c.
4 a.m.	- 8 a.m.	42.5 „	clearer, yellow		= .3584 grm.
					per 100 c.c.
		<hr/>			
		285 c.c.			

Urine.—8 a.m. – 8 p.m. 15 oz. sp. gr. 1020 *Urea* 3·4 %
 8 p.m. – 8 a.m. 15 oz. sp. gr. 1015 „ 1·7

Diet, ordinary. Bowels moved after exhibition of Cascara. Motion dark and apparently normal.

		June 11th.	Quantity of Bile.		
8 a.m.	– 12 noon	40	c. c.	greenish golden	{ .2441 grm. Salts in 50 c.c. = .4882 grm. per 100 c.c.
12 noon	– 4 p.m.	66	„	darker, hazy	
4 p.m.	– 8 p.m.	36	„	golden greenish	
8 p.m.	– 12 mdnt.	42	„	„ hazy	{ .0292 grm. Salts in 50 c.c. = .0584 grm. per 100 c.c.
12 mdnt.	– 4 a.m.	7.5	„	clear yellow	
4 a.m.	– 8 a.m.	40	„	dark greenish, hazy	
		<hr/> 281.5 c.c.			

Urine.—8 a.m. – 8 p.m. 9 oz., sp. gr. 1022 some lost (during purgation) *Urea* 2·5 %
 8 p.m. – 8 a.m. 8 oz., sp. gr. 1015 „ „ „ 1·7

Diet, ordinary. Bowels still moving after exhibition of Cascara. Soft, dark-coloured motion, having bad odour.

		June 12th.	Quantity of Bile.		
8 a.m.	- 12 noon	65	c.c.	orange hazy	{ ·0517 grm. Salts in 50 c.c. = ·1034 grm. per 100 c.c.
12 noon	- 4 p.m.	22	,,	clear golden	
4 p.m.	- 8 p.m.	42	,,	golden, slightly hazy	
8 p.m.	- 12 mdnt.	11·5	,,	greenish, hazy	{ ·0299 grm. Salts in 50 c.c. = ·0598 grm. per 100 c.c.
12 mdnt.	- 4 a.m.	35	,,	hazier	
4 a.m.	- 8 a.m.	42	,,	still darker green	
		<hr/> 217·5 c.c.			

Urine.—8 a.m. - 8 p.m. 9 oz., sp. gr. 1020 Urea 2·6 %
8 p.m. - 8 a.m. 12 oz., sp. gr. 1012 ,, 1·1

Diet, ordinary, but it is to be altered to-morrow, substituting, at dinner, farinaceous food for flesh-meat. Since yesterday the following has been taken, up to 8 a.m. this morning :—

8 a.m. Cocoa, 14 oz., 1 slice of toast, fish.
12 noon. Soda water, 2 oz.
1 p.m. Soup, 14 oz., piece of chicken, $\frac{1}{2}$ slice bread.
2 p.m. Soda water, 2 oz.
4.30 p.m. Tea, 8 oz., 1 slice bread.
9 p.m. Whisky, 1 oz., water, 2 oz., and biscuit.
4 a.m. Cocoa, 12 oz., 1 slice bread.
6.80 a.m. Whisky, 1 oz., water, 1 oz.

		June 13th.	Quantity of Bile.		
8 a.m.	- 12 noon	21 c.c.	greenish hazy	{	·0365 grm. Salts in 50 c.c. = ·0730 grm. per 100 c.c.
12 noon	- 4 p.m.	28 „	golden, clearer		
4 p.m.	- 8 p.m.	65 „	slightly greenish, hazy		
8 p.m.	- 12 mdnt.	57 „	dark" greenish" „	{	·1410 grm. Salts in 50 c.c. = ·2820 grm. per 100 c.c.
12 mdnt.	- 4 a.m.	41 „			
4 a.m.	- 8 a.m.	45 „			
		<hr/> 257 c.c.			

Urine.—8 a.m. - 8 p.m. 22 oz., sp. gr. 1014 Urea 1·1 %
8 p.m. - 8 a.m. 25 $\frac{1}{2}$ oz., sp. gr. 1012 ,, ·8 Deposit of urates.

Diet : The following represents dietary since 8 a.m. yesterday :—

8 a.m. Cocoa, 14 oz., 1 slice bread, fish	9 p.m. Whisky, 1 oz., water, 2 oz., biscuit.
9 a.m. Water, 2 oz.	4 a.m. Cocoa, 12 oz., toast, $\frac{1}{2}$ slice.
1 p.m. Rice and milk, 14 oz.	6 a.m. Whisky, 1 oz., water, 1 oz.

		June 14th.	Quantity of Bile.		
8 a.m.	- 12 noon.	41·5 c.c.	greenish yellow, hazy	{	·2695 grm.
12 noon	- 4 p.m.	31·5 „	clear golden yellow		Salts in 25 c.c.
4 p.m.	- 8 p.m.	15 „	„ „		- 1·0780 grm.
					per 100 c.c.
8 p.m.	- 12 mdnt.	53 „	pale green, hazy	{	·3072 grm.
12 mdnt.	- 4 a.m.	54 „	darker green, hazy		Salts in 25 c.c.
4 a.m.	- 8 a.m.	46 „	still darker „		- 1·2288 grm.
					per 100 c.c.
		<hr/>			
		241 c.c.			

Urine.—8 a.m. - 8 p.m. 23 oz., sp. gr. 1012 Urea ·6 %
8 p.m. - 8 a.m. 8 oz., ,, 1012 ,, 1·3

Diet, as yesterday.

June 15th. Quantity of Bile.

8 a.m. - 12 noon.	34 c.c.	greenish orange, slight haze	{	.1684 grm.
12 noon - 4 p.m.	22 "	" " "		Salts in 25 c.c.
4 p.m. - 8 p.m.	28 "	" " clearer		= .6736 grm.
				per 100 c.c.
8 p.m. - 12 mdnt.	42 "	" " hazy	{	.2296 grm.
12 mdnt. - 4 a.m.	11 "	greener, hazy		Salts in 25 c.c.
4 a.m. - 8 a.m.	30 "	Greener still. Very hazy		= .9184 grm.
				per 100 c.c.

167 c.c.

Urine.—8 a.m. - 8 p.m. 20 oz., sp. gr. 1015 *Urea* 1.7 %

8 p.m. - 8 a.m. 8 oz., sp. gr. 1012. Some lost during purgation.

Diet, as yesterday. At 2 a.m., 1 oz. castor oil administered.*June 16th. Quantity of Bile.*

8 a.m. - 12 noon	17.5 c.c.	greenish tint, hazy	{	.3780 grm.
12 noon - 4 p.m.	17.5 "	" " "		Salts in 25 c.c.
4 p.m. - 8 p.m.	40 "	orange, hazy		1.5120 grm.
				per 100 c.c.
8 p.m. - 12 mdnt.	3.5 "	yellow, hazy	{	.0250 grm.
12 mdnt. - 4 a.m.	33.25 "	light yellow, hazy		Salts in 25 c.c.
4 a.m. - 8 a.m.	40 "	orange, hazy		= .1000 grm.
				per 100 c.c.

151.75 c.c.

Urine.—8 a.m. - 8 p.m. 12 oz., sp. gr. 1022 *Urea* 1.4 %

8 p.m. - 8 a.m. 15 oz., sp. gr. 1018 " 2.5

Diet, same as yesterday.*June 17th. Quantity of Bile.*

8 a.m. - 12 noon	21 c.c.	clear golden	{	Bile thrown out by mistake before estima- tion made.
12 noon - 4 p.m.	27 "	golden, slight haze		
4 p.m. - 8 p.m.	32 "	" clearer		
8 p.m. - 12 mdnt.	8 "	" hazy		
12 mdnt. - 4 a.m.	20 "	bright, orange hazy		
4 a.m. - 8 a.m.	43 "	greenish "		

151 c.c.

Urine.—8 a.m. - 8 p.m. ? oz., sp. gr. 1025 urates deposited *Urea* 2.3 %

8 p.m. - 8 a.m. 8 oz., " 1022 " 3.3

Diet, resumption of ordinary mixed ; mince and soup to dinner.*June 18th. Quantity of Bile.*

8 a.m. - 12 noon	30 c.c.	golden greenish hazy	{	.1722 grm.
12 noon - 4 p.m.	55 "	darker green "		Salts in 25 c.c.
4 p.m. - 8 p.m.	21 "	glear golden yellow		= .6888 grm.
				per 100 c.c.
8 p.m. - 12 mdnt.	9 c.c.	golden hazy	{	.0956 grm.
12 mdnt. - 4 a.m.	7 "	" "		Salts in 25 c.c.
4 a.m. - 8 a.m.	16 "	" "		= .3824 grm.
				per 100 c.c.

138 c.c.

Urine.—8 a.m. - 8 p.m. 14.5 oz., sp. gr. 1024 urates deposited *Urea* 3.5 %

8 p.m. - 8 a.m. 12 oz., " 1021 " 2.2

Diet, ordinary mixed.

June 19th. Quantity of Bile.

8 a.m. - 12 noon	23 c.c.	orange, hazy	{	.2078 grm.
12 noon - 4 p.m.	46.5 "	" clearer		Salts in 25 c.c.
4 p.m. - 8 p.m.	17.5 "	" "		= .8312 grm.
				per 100 c.c.
8 p.m. - 12 mdnt.	41.5 "	" becoming hazy	{	.1652 grm.
12 mdnt. - 4 a.m.	46.5 "	dark green, opaque		Salts in 25 c.c.
4 a.m. - 8 a.m.	41 "	" " "		= .6608 grm.
				per 100 c.c.
<hr/>				
216 c.c.				

Urine.—8 a.m. - 8 p.m. 12 oz., sp. gr. 1024 Urea 1.8 %
 8 p.m. - 8 a.m. 46 oz., " 1011 " .6

Diet, ordinary mixed.

A saline aperient consisting of Sulphates of Magnesia (3iii) and Soda (3vi) given at 4 a.m., but vomited at 4.10 a.m. On our visiting the patient at 9 o'clock this morning, she is found greatly depressed and desiring to go home; she says that salts have "never agreed with her." In bile-specimens taken during the night there is plentiful mucus, with blood corpuscles entangled in it. This may have come about from the mucous membrane of the gall-bladder having been injured by tube while the patient was vomiting. No action of the bowels having followed the saline, 5 grains of calomel were ordered to be taken to-night. Although there was no movement of bowels after the salts, she complained of great thirst.

June 20th. Quantity of Bile.

8 a.m. - 12 noon.	13.5 c.c.	green, hazy	} .2344 grm. Salts in 25 c.c. = .9376 grm. per 100 c.c.
12 noon - 4 p.m.	26 "	golden, slightly hazy	
4 p.m. - 8 p.m.	13.5 "	" "	
8 p.m. - 12 mdnt.	51 "	Bright golden, clear	} Specimen lost during analysis.
12 mdnt. - 4 a.m.	15.5 "	" hazy	
4 a.m. - 8 a.m.	24 "	" "	
<hr/>			
148.5 c.c.			

Urine.—8 a.m. - 8 p.m., 24 oz., sp. gr. 1020 Urea 1.5 %
 8 p.m. - 8 a.m. 20 oz., " 1010 " .5 Some urine lost.

Diet, ordinary mixed. 5 grains of Calomel administered at 10 p.m. (last night). Bowels moved 4 times, the stools being natural in colour and not so offensive as on previous occasions. Unfortunately some urine lost, preventing total estimation of urea being made.

June 21st. Quantity of Bile.

8 a.m. - 12 noon.	9 c.c.	orange, hazy	}	.1768 grm., <i>Salts</i> in 25 c.c.	
12 noon - 4 p.m.	22 „	„ clear		}	= .7072 grm. per 100 c.c.
4 p.m. - 8 p.m.	15 „	„ „			.1290 grm., <i>Salts</i> in 12.5 c.c.
8 p.m. - 12 mdnt.	8.5 „	„ „	}		= 1.0320 grm. per 100 c.c.
12 mdnt. - 4 a.m.	5 „	„ „			
4 a.m. - 8 a.m.	11 „	„ „			
<hr/>					
70.5 c.c.					

Urine.—8 a.m. - 8 p.m. 15 oz., sp. gr. 1020 Urea 2.3 %
 8 p.m. - 8 a.m. 16.5 oz., sp. gr. 1012 " 1.1

Diet, ordinary mixed.

June 22nd. Quantity of Bile.

8 a.m. - 12 noon	14 c.c.	faint greenish, hazy	} .1484 grm. Salts in 25 c.c. = .5936 grm. per 100 c.c.
12 noon - 4 p.m.	22 „	yellowish, clearer	
4 p.m. - 8 p.m.	31 „	„ „	
8 p.m. - 12 mdnt.	46 „	„ clearer still	} .1894 grm. Salts in 25 c.c. = .7576 grm. per 100 c.c.
2 mdnt. - 4 a.m.	8 „	„ „	
4 a.m. - 8 a.m.	46 „	dark-golden, clear	
<hr/> 167 c.c.			

Urine.—8 a.m. - 8 p.m. 24 oz., sp. gr. 1018 Urea 1.5 %
8 p.m. - 8 a.m. 18.5 oz., „ 1010 „ .5

Diet, ordinary mixed.

June 23rd. Quantity of Bile.

8 a.m. - 12 noon	14 c.c.	golden, hazy	} .1500 grm. Salts in 25 c.c. = .6000 grm. in 100 c.c.
12 noon - 4 p.m.	21.5 „	paler	
4 p.m. - 8 p.m.	22 „	„	
8 p.m. - 12 mdnt.	38 „	golden, hazy	} .2802 grm. Salts in 25 c.c. = 1.1208 grm. in 100 c.c.
12 mdnt. - 4 a.m.	10 „	„ „	
4 a.m. - 8 a.m.	36 „	dark greenish. Very hazy.	
<hr/> 141.5 c.c.			

Urine.—8 a.m. - 8 p.m. 24 oz., sp. gr. 1015 Urea .6 %
8 p.m. - 8 a.m. 9 oz., sp. gr. „ .7

Diet, ordinary mixed.

V. General Conclusions.

The following points present themselves for consideration and will be briefly noted :—

A. Quantity of Bile.

- | | |
|---------------------------------------|----------------------------|
| (a) Secreted in 24 hours. | (δ) Relation to drugs. |
| (β) Relation to time of day. | (ε) „ „ quantity of urine. |
| (γ) Relation to food { i. meal hours. | (ζ) „ „ temperature. |
| ii. nature of food. | |

*B. Colour of Bile.**C. Specific Gravity.**D. Reaction.**E. Bile-Salts.*

- | | |
|----------------------------|-----------------------|
| (a) Time of day, or night. | (δ) Relation to Urea. |
| (β) Relation to diet. | (ε) „ „ temperature. |
| (γ) „ „ drugs. | |

A. (a). Quantity secreted in 24 hours.

This varies within wide limits. The minimum quantity was collected on the 21st June, viz. 70.5 c.c.; while the maximum

occurred on the 10th of same month, viz. 285.5 c.c. The average daily quantity over 18 days is 191.22 c.c.

Bearing in mind (p. 217) that there was reason to suppose a free escape into the intestine, the above figures of course are not indicative of the total secretion.

(β). *Relation to 4-hourly period of 24 hours at which collected.*

The greatest quantity collected in a 4-hourly period is seen below, for the different days :—

Date.	Quantity.	4-Hourly Period.	
June 6,	45 c.c.	12 noon - 4 p.m.	
" 7,	66 "	12 mdnt. - 4 a.m.	
" 8,	63 "	8 p.m. - 12 mdnt.	From the figures in preceding pages the following <i>average</i> has been arrived at :—
" 9,	49 "	8 a.m. - 12 noon.	
" 10,	65 "	4 p.m. - 8 p.m.	
" 11,	66 "	12 noon - 4 p.m.	
" 12,	65 "	8 a.m. - 12 noon.	
" 13,	65 "	4 p.m. - 8 p.m.	
" 14,	54 "	12 mdnt. - 4 a.m.	
" 15,	42 "	8 p.m. - 12 mdnt.	
" 16,	40 "	4 p.m. - 8 p.m.	
" 16,	40 "	4 a.m. - 8 a.m.	
" 17,	43 "	4 a.m. - 8 a.m.	
" 18,	55 "	12 noon - 4 p.m.	
" 19,	46.5 "	12 noon - 4 p.m.	
" 19,	46.5 "	12 mdnt. - 4 a.m.	
" 20,	51 "	8 p.m. - 12 mdnt.	
" 21,	22 "	12 noon - 4 p.m.	
" 22,	46 "	8 p.m. - 12 mdnt.	
" 22,	46 "	4 a.m. - 8 a.m.	
" 23,	38 "	8 p.m. - 12 mdnt.	

8 a.m. - 12 noon	29.50 c.c.
12 noon - 4 p.m.	33.50 "
4 p.m. - 8 p.m.	30.90 "
8 p.m. - 12 mdnt.	36.02 "
12 mdnt. - 4 a.m.	25.31 "
4 a.m. - 8 a.m.	37.62 "

Average in 24 hours = 192.85 c.c.

Average maximum - 4-8 a.m.
,, minimum - 12-4 a.m.

These figures show the maximum quantity excreted during a period of 4 hours to be far from constant to any one period of the day. We have the daily maximum occurring from 12 noon-4 p.m. on five occasions, and for a similar number of times from 8 p.m.-12 midnight. On three occasions each the maximum is noted as occurring at the following periods: 12 midnt.-4 a.m.; 4 p.m.-8 p.m., and 4 a.m.-8 a.m.; while from 8 a.m.-12 noon, we have the maximum flow on two occasions only.

In addition, it is found that on one occasion the maximum flow occurred; (1) from 4 p.m.-8 p.m. and 4 a.m.-8 a.m. on the same day; (2) on another at 12 noon-4 p.m. and 12 midnt.-4 a.m.; and (3) again at 8 p.m.-12 midnt. and 4 a.m.-8 a.m.

(γ). *Relation to taking of food.*

(i.) *Meal-hours: Breakfast, 8 a.m.* On five occasions maximum flow occurred from 12 noon–4 p.m., but on one of these an equal flow was observed from 12 midnt.–4 a.m. Maximum occurred twice from 8 a.m.–12 noon.

Dinner, 1 p.m. Again maximum noted as occurring on five occasions from 12 noon–4 p.m.

Tea, 4 p.m. Maximum on three occasions from 4 p.m.–8 p.m.; but on one of these there was an equal flow from 4 a.m.–8 a.m. These observations do not bear out the existence of a relationship between the taking of food and the secretion of bile. See below, explanation offered at end of (δ.).

(ii.) *Nature of food:* According to the charts Nos. 1 and 3, there seems to be some falling off when reduced diet is being taken. This, however, is not at all marked when compared with the register following the resumption of the original diet.

(δ). *Drugs.*

(i.) At 2 a.m. on 6th June, *Castor Oil* $\frac{1}{2}$ oz. taken. From 12 midnt. to 4 a.m. 15 c.c. bile collected, while from 4–8 a.m., 44 c.c. and from 8 a.m.–12 noon, 48 c.c.

(ii.) At 11 p.m. on 11th June, *Cascara Sagrada* (Liq. Extr. 3 i) administered. For each period of the 24-hours-day the quantity remained between 40 and 50 c.c. and no marked effect on the quantity seems to have followed the exhibition of this laxative.

(iii.) At 2 a.m. on the 15th, *Castor Oil* 1 oz. administered. For the following 24 hours, the quantities of bile seem to be somewhat below the usual, keeping for the most part under 40 c.c., and at 12 midnight dropping to 3·5 c.c.

(iv.) *Saline Aperient* (Magnes. Sulph. 3 iii Sod. Sulphat. 3 vi) given at 4 a.m. on 19th. From 8 a.m.–8 p.m. there was a decided drop in the quantity collected. At 12 midnight it had risen to 50 c.c. (*Calomel* gr. v having been administered at 10 p.m.). She vomited the salts about 10 minutes after having taken them. The quantities collected were very low during the 32 hours following the administration of the calomel, being

for the most part below 20 c.c. They then began to creep up, ranging about the 40's.

The explanation offered of the fall in quantity after the administration of the above drugs (with the exception of Cascara) is, that more of the bile flowed into the active intestine than when the viscera were in a state of rest. Perhaps this explanation may account for absence of apparent relationship between bile-flow and taking of food, noted above.

(e). *Urine.*

On reference to Chart No. 3, it will be seen, so far as is shown—the urine having been lost occasionally, as after purgation—that there is a relation between the quantity of this secretion and that of the bile. When the bile-register keeps high and more or less uniform, the urine keeps low and uniform. When, however, towards the end of the chart, the bile-tracing comes down, that of the urine jumps up. It is felt that the observations on this point are too scanty to be of much worth; nevertheless it is thought well to record them.

(f). *Temperature.*

We lastly come to consider the relation, if any, between the patient's body-temperature and the quantity of bile collected.

Throughout the time during which the observation was being carried on the temperature showed very little oscillation, and any there is can hardly be said to bear any relation to the bile-curve.

B. *Colour of the Bile.*

This varies much, both in the 24 hours and from day to day. It seems, however, to be of dark greenish tint from 12–4 a.m. and 4 a.m.–8 a.m. as a rule, although sometimes the day specimens show this colour, while those collected at night are golden-yellow and clear.

Drugs seem to influence this:—Cascara, 11 p.m. on 9th June. Darkening of colour of night specimens to greenish hue, to be followed in a day or so by orange-yellow bile, after which the greenish colour is again observed.

On the 15th June, Castor Oil followed by greenish bile. On the 16th, the bile is mostly orange or golden-yellow.

After salts on the 19th the colour is dark green and opaque, while after Calomel on evening of 19th the bile is golden and clear on to the 22nd June. By the 23rd June, it is observed to be returning to general condition of "dark greenish, hazy" in the morning.

C. *Specific Gravity of Bile.*

This was only irregularly taken, but the following results were obtained:—

Average of 8 day-specimens	=	1011·75.
„ „ 6 night- „	=	1012·50.

So far as shown, drugs had no influence on the specific gravity. There is no relation between the quantity of bile collected and the specific gravity.

D. *Reaction of Bile.*

Tested on eighteen occasions and found always to be faintly alkaline.

E. *Bile-salts (Glycocholate and Taurocholate of Soda.*

As will be seen on referring to Chart No. 2, the quantity of salts excreted from fistula varies within wide limits.

(a). *Influence of time of day or night :—*

Average for day	=	0·4840	gram.	(0·5249	gram. per 100 c.c. bile).
„ „ night	=	0·4957	gram.	(0·5231	gram. per „ „

(β). *Relation to food (referring to diet).*

Up to 13th June, the patient was taking ordinary mixed diet (as on p. 221). On that date farinaceous food was substituted for the ordinary dinner of flesh-meat. On the 13th, morning-salts = ·07 gram., evening ditto = ·4 gram., while on 14th the morning-salts = ·94 gram., evening = 1·86 gram. On the morning of 15th, they were down to ·56 gram., evening ·75 gram.

(Castor Oil 3 i was taken at 2 a.m. on 15th). On 16th, salts of morning specimen = 1.13 grm., while on the evening of this day they fell to .07 grm.

The original mixed diet was resumed on the following day, but by some mistake the specimens of bile were thrown out before having been analysed.

On the 18th, morning = .72 grm.; evening = .12 grm.

„ . „ 19 „ „ = .74 grm. „ = .85 grm.

At 4 a.m. on 19th, Saline administered (Sulph. of Magnesia 3 iii and of Soda 3 vi) on account of constipation. The patient received also at 10 p.m. 5 grs. Calomel. The analysis for 20th (including from 8 a.m. 19th) is as follows:—

Morning = .49 grm. The evening specimen lost during analysis owing to an accident to the apparatus. The Calomel was administered on account of the salts having been vomited and was followed by a lively catharsis. Analysis for 21st June was as follows:—morning = .32 grm.; evening = .25 grm.

There was slight rise on succeeding day to .39 and .75 for morning and evening respectively. The 23rd = morning .34 grm., evening .94 grm.

From the above details it seems that the withdrawal of flesh-meat from the dietary is followed by increase in the quantity of the bile-salts, while on resumption of flesh-diet there is a fall. It is unfortunate that only the quantity for day succeeding and not that for day of resumption is determined. There is, towards the close of chart, a tendency to creep up.

(γ). *Drugs.*

The administration of Ol. Ricini is followed by an increase and subsequent decrease in quantity of the salts. The saline seems to have had but little effect on the salts (bile), while the effect of the Calomel cannot be ascertained. Judging from other parts of the chart, the fall on the 21st might indicate a rise on the 20th.

(δ). *Relationship to Urea.*

This is shown in a marked way in Chart No. 2, in which the tracings of urea and bile-salts are compared. As the quantity

of salts rises, there is almost invariably a fall in urea, while the converse also holds good. When the rise of salts follows the modification of diet, the urea is seen to fall. The effect of drugs on this relationship cannot be seen on account of the patient's sex.

While it is noted that on last day of observation the bile-salts show a tendency to creep up, this is checked by the fall in the excretion of the urea.

When the *percentage* of salts is considered, similar results obtain.

(*ε*). *Temperature.*

Same remarks apply here as on p. 227, where the temperature-notes are compared with quantity of bile secreted.

N.B.—The bile decomposed readily during hot weather.

SUMMARY.

1. Quantity of bile collected varies much.
2. The variation is not regular for any period of the day, the occurrence of the maximum being very variable. The average maximum occurs at 4–8 a.m.; minimum 12–4 a.m.
3. The variation shows no relation to meal-hours.
4. Effect of change of diet is doubtful.
5. The various purgatives employed (with exception of Cascara) are followed by diminished discharge from the fistula. Does more of the bile pass into the active intestine?
6. Quantity of bile discharged varies inversely as that of the urine.
7. As a rule, bile collected during the night-hours is of a dark greenish tint.
8. Greenish colour follows exhibition of purgatives, and is succeeded by change to golden-yellow.
9. Specific gravity low, but higher at night than through the day.
10. Reaction, so far as taken, faintly alkaline.
11. Average salts slightly lower by day than by night.
12. Farinaceous food followed by increase of salts. On resumption of flesh-meat, salts do not drop to former level.

13. Effect of drugs on salts not satisfactorily determined.
14. There is very distinct inverse relation of salts to excretion of urea.
15. Antisepticity of bile low.

VI. *Comparison with other Observers.*

The variation in quantity excreted is mentioned by others. Our observations as to the average minimum and maximum do not agree with those of Paton and Balfour (¹):—

Paton and Balfour.			Present Observations.	
8 a.m.	– 12 noon	106·0 c.c.	29·50 c.c.	
12 noon	– 4 p.m.	140·5 „	33·50 „	
4 p.m.	– 8 p.m.	102·0 „	30·90 „	
8 p.m.	– 12 mdnt.	100·6 „	36·02 „	
12 mdnt.	– 4 a.m.	88·5 „	25·31 „	
4 a.m.	– 8 a.m.	116·0 „	37·62 „	

Copeman and Winston (²) find rate of secretion lowest at 5 a.m., highest at 12 noon, and this they attribute to the taking of food. The researches of Yeo and Herroun (³) show no increase after meals; they also say that amount secreted during day is same as that during night. They are willing to believe, however, that while this result may be obtained in hospital, where meals are frequent and moderate, yet a different state might obtain where meals were larger and taken at longer intervals. Mayo Robson (⁴), on the other hand, finds a rise in quantity at night. He also finds change of diet not followed by any great alteration in the quantity of the bile secreted, and his results point to a diminution in quantity following the administration of chologogues, agreeing with our experience with purgatives (?).

Specific gravity is in our case in accordance with the results of others, being about 1011. Jacobsen (quoted by Halliburton ⁵) draws attention to the difference between fistula-bile and gall-bladder-bile in this respect. We find it higher at night, and in this agree with Paton and Balfour. These observers, and also Mayo Robson, agree with us as to increased secretion of bile-salts during the night. As will be seen below, however, our percentage is higher for day than night. The following table gives a comparison of different observations, and is taken from Paton and Balfour's paper.

	Jacobsen.	Yeo and Herroun.	Copeman and Winston.	Robson.	Paton and Balfour.		Present Case.
Sod. Glyco- cholate, .	1.01	.165	} .628 ... }	.751	.356	} .349 } }	} .524 } }
Sod. Tauro- cholate, .	...	.055		.009	.049		

Paton and Balfour.		Present Case.	
8 a.m.—8 p.m.	8 p.m.—8 a.m.	8 a.m.—8 p.m.	8 p.m.—8 a.m.
.2426	.4571	.5249	.5231
.349		.524	

As regards general metabolism, we find with ordinary mixed diet less salts formed than with farinaceous modification. This is also borne out in comparing with the urea excreted, and this seems to be in agreement with the results of Kunkel and Spirs (quoted by Bunge⁶), who show that only a small part of nitrogen and sulphur resulting from proteid metabolism appears in bile. Mayo Robson and Paton (⁷) and Balfour agree as to excrementitious nature of the bile; and Zweifel (quoted by Bunge) declares that the bile must to a certain extent be excretory, seeing that it is formed during the third month of embryonic life, whereas secretions from other glands for intestinal tract begin after birth, on taking of food.

Most are agreed on the question of the low antisepticity of bile. (See Tables, p. 234.)

Note.—Since writing the above, I have had an opportunity of observing another case of biliary fistula. The patient was operated on by Dr Henry Rutherford for gallstones. The gall-ducts were patent, but a biliary fistula existed for some time after the operation, and from this considerable quantities of bile were passed. It was observed that the discharge of bile was increased very much by exhibition of Seidlitz powder, or Colocynth pill, a matter of frequent occurrence on account of constipation.

The increase was such as to require additional dressings to be applied over the fistula.

VII. References.

- (1.) *Laboratory Reports, Royal College of Physicians, Edinburgh*, vol. iii., 1891.
- (2.) *Journal of Physiology*, vol. x. p. 213, 1889.
- (3.) " " vol. v. p. 116, 1884.
- (4.) *Proc. Royal Society*, vol. xlvii. p. 499, 1890.
- (5.) Halliburton, *Text-book of Chemical Physiology and Pathology*, 1889, p. 675.
- (6.) *Physiological and Pathological Chemistry*, Bunge, trans. by Wooldridge, 1890, p. 214.
- (7.) *Laboratory Reports, Royal College of Physicians, Edinburgh*, vol. iv., 1892.
- (8.) *Foster's Physiology*. Appendix. Sheridan Lea. p. 211.

[TABULAR STATEMENT.

TABULAR STATEMENT.

Bile.										Urina.			
Date.	Hour.	Quantity in c.c.	Specific Gravity.	Salts.		Quantity in os.	Specific Gravity.	Urea.		Temp.			
				Per- centage.	Total in Grammes.			Per- centage.	Total in Grammes.				
1895. June 6.	8 a.m. - 12 noon	17	..	}	..	15	1014	}			
	12 noon - 4 p.m.	45	..										
	4 p.m. - 8 p.m.	26.5	..										
	8 p.m. - 12 midnt.	19	..										
	12 midnt. - 4 a.m.	15	..										
	4 a.m. - 8 a.m.	44	..										
		156.5	21				
" 7.	8 a.m. - 12 noon	48	..	}	..	14	1024	}			
	12 noon - 4 p.m.	9	..										
	4 p.m. - 8 p.m.	17	..										
	8 p.m. - 12 midnt.	25	..										
	12 midnt. - 4 a.m.	66	..										
	4 a.m. - 8 a.m.	26.5	..										
		221.5	26				
" 8.	8 a.m. - 12 noon	22	..	}	14	13	1024	}			
	12 noon - 4 p.m.	28	..										
	4 p.m. - 8 p.m.	23	..										
	8 p.m. - 12 midnt.	63	..										
	12 midnt. - 4 a.m.	16.5	..										
	4 a.m. - 8 a.m.	50	..										
		218.5	10	1025		..				
" 9.	8 a.m. - 12 noon	49	..	}	21	23	..	}			
	12 noon - 4 p.m.	43	..										
	4 p.m. - 8 p.m.	49	..										
	8 p.m. - 12 midnt.	45.5	..										
	12 midnt. - 4 a.m.	43	..										
	4 a.m. - 8 a.m.	49.75	..										
		271.25	9	1020		..				
" 10.	8 a.m. - 12 noon	49	..	}	22	8	1016	}			
	12 noon - 4 p.m.	43	..										
	4 p.m. - 8 p.m.	49	..										
	8 p.m. - 12 midnt.	45.5	..										
	12 midnt. - 4 a.m.	43	..										
	4 a.m. - 8 a.m.	49.75	..										
		271.25	17				

1895. June 10.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	51.5 51 66 55 20.5 42.5	.. .. .. .. .. ..	.. .. .. .. .. ..	.. .. .. .. .. ..	2432 3384	.40 .41	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	16 16	1020 1016	3.4 1.7	14.48 7.24	M. 97.8 E. 97.8	Motions passed, dark brown colour, bad odour, apparently normal.
		285.5	..	..	.81	..			20	..	..	21.72		
" 11.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	40 66 36 42 7.5 40	............	............	.68 .04	4882 0584		8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	9* 8*	1022 1015	2.5 1.9	.. ..	M. 97.6 E. 98.4	* Some lost. * " "
		231.5	..	..	.72	..			17	..	..	..
" 12.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	65 32 42 11.5 36 42	............	............	.12 .04	1084 0598		8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	9 12	1020 1012	2.6 1.1	6.64 3.74	M. 97.2 E. 98	
		217.5	..	..	.16	..			21	..	..	10.88		
" 13.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	21 28 65 57 41 45	............	............	.07 .40	0730 2820		8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	22 25.5	1014 1012	1.1 .8	6.87 5.79	M. 97.2 E. 98.6	Diet modified.
		257	..	..	.47	..			47.5	..	..	12.66		
" 14.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	41.5 31.5 15 53 54 46	............	............	.94 1.86	10780 12268		8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	23 8	1012 1012	.6 1.3	3.91 2.95	M. 98.8 E. 98.6	
		241	..	..	2.80	..			31	..	..	6.86		

TABULAR STATEMENT—continued.

Date.	Hour.	Bile.				Urine.				
		Quantity in c.c.	Specific Gravity.	Salts.		Quantity in oz.	Specific Gravity.	Urea.		Temperature ° F.
				Per- centage.	Total in Grammes.			Per- centage.	Total in Grammes.	
1895. June 16	8 a.m. - 12 noon	24	1011	.6738	46	20	1015	1.7	9.65	M. 97
	12 noon - 4 p.m.	23								
	4 p.m. - 8 p.m.	28	1013	.9184	76	8	1012	2	..	E. 97.8
	8 p.m. - 12 midnt.	42								
	12 midnt. - 4 a.m.	11								
	4 a.m. - 8 a.m.	80								
		167	..	..	1.81	..	..	..	..
" 16.	8 a.m. - 12 noon	17.5	1013	1.6120	1.13	13	1022	1.4	4.77	M. 97
	12 noon - 4 p.m.	17.5								
	4 p.m. - 8 p.m.	40	1014	1.000	.07	16	1018	2	8.61	E. 96.8
	8 p.m. - 12 midnt.	3.5								
	12 midnt. - 4 a.m.	38.25								
	4 a.m. - 8 a.m.	40								
		151.75	..	..	1.20	..	..	..	19.28	
" 17.	8 a.m. - 12 noon	21	1011	..	..	..	1025	2.2	..	..
	12 noon - 4 p.m.	27								
	4 p.m. - 8 p.m.	82	1013	..	..	8	1022	3.9	7.60	..
	8 p.m. - 12 midnt.	8								
	12 midnt. - 4 a.m.	20								
	4 a.m. - 8 a.m.	43								
		131	..	..	..	..	..	..	..
" 18.	8 a.m. - 12 noon	30	1014	.9368	.72	14.6	1024	8.0	12.35	M. 96.2
	12 noon - 4 p.m.	56								
	4 p.m. - 8 p.m.	31	..	.8834	.12	12	1021	2.2	7.5	E. 96.8
	8 p.m. - 12 midnt.	9								
	12 midnt. - 4 a.m.	7								
	4 a.m. - 8 a.m.	16.5								
		128.6	..		.64	96.5			19.85	

1895. June 19.	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	93 46.5 17.5 41.5 46.5 41	1013 1012	.8312 .8808	.74 .85	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	12 46	1024 1011	1.8 .6	6.13 7.84	M. 97.4 E. 97.6	Sod. sulph. (3vi) and Magn. sulph. (3iii) at 4 a.m.
"	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	216 13.5 26 13.5 51 15.5 24	.. 1012 1013	.. .9376 *	1.59 .49 ..	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	58 24 20.†	.. 1020 1010	.. 1.5 .5	13.97 10.22 ..	M. 98.6 E. 98.2	Calomel (gr. v.) at 10 p.m. * Lost in analysis. † Some urine lost.
"	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	143.5 9 22 15 8.5 5 11	.. 1011..	...7072 1.0320	.. .32 .25	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	.. 15 16.5	.. 1020 1012	.. 2.3 1.1	.. 9.79 5.15	M. 98 E. 97	
"	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	70.5 14 22 31 46 8 46	.. 1011 1013	.. .5936 .7576	.57 .39 .75	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	.. 24 18.5	.. 1018 1010	.. 1.5 .5	14.94 10.22 2.62	M. 97.4 E. 98.4	
"	8 a.m. - 12 noon 12 noon - 4 p.m. 4 p.m. - 8 p.m. 8 p.m. - 12 mdnt. 12 mdnt. - 4 a.m. 4 a.m. - 8 a.m.	167 14 21.5 22 28 10 36	......	...6000 1.1908	1.14 .34 .94	8 a.m. - 8 p.m. 8 p.m. - 8 a.m.	.. 24 9	.. 1015..	...6 .5	12.84 4.09 1.27	M. 98 E. 98.4	
"		141.5	..	..	1.28		..	..	..	5.86		

NOTES ON THE ANATOMY OF AN ANENCEPHALOUS
FŒTUS HAVING THREE ARMS AND THREE
LOWER LIMBS. By F. G. PARSONS, F.R.C.S., *Demon-
strator of Anatomy at St Thomas's Hospital.*

(Read before the Anatomical Society, Nov. 22, 1895.)

THE foetus from which the following notes were taken was kindly placed at my disposal by Professor Stewart. The skeleton is now in the Museum of the Royal College of Surgeons, and the necessity for preserving this intact made the dissection rather less complete than it might otherwise have been. I am inclined to regard this specimen as worthy of being recorded, because in the literature to which I have had access I have been unable to discover anything resembling it, and also because Professor Windle tells me that he has never met with a similar case. The references to other descriptions which seem to have a bearing on this specimen have been reserved until the end of the paper.

EXTERNAL ANATOMY.

Viewed from the right side, the specimen is that of an ordinary anencephalous foetus, but on the left side there are two arms and two lower limbs; as one of these is a little in advance of the other, they are best distinguished by the name of anterior and posterior left arm and lower limb respectively. The anterior left arm, which I look upon as the left arm of the primary foetus, is only remarkable for being very much shrunken in circumference but not much in length. The posterior left arm is double in its lower part; that is to say, evidences of two olecranon processes can be made out, and the hand is double, with the flexor surfaces of the fingers turned towards one another. This posterior left upper extremity I regard as the fused arms of a parasitic foetus. On looking at the left side of the abdomen and thorax, and comparing it with the right, it is evident that the trunk is asymmetrical; in other

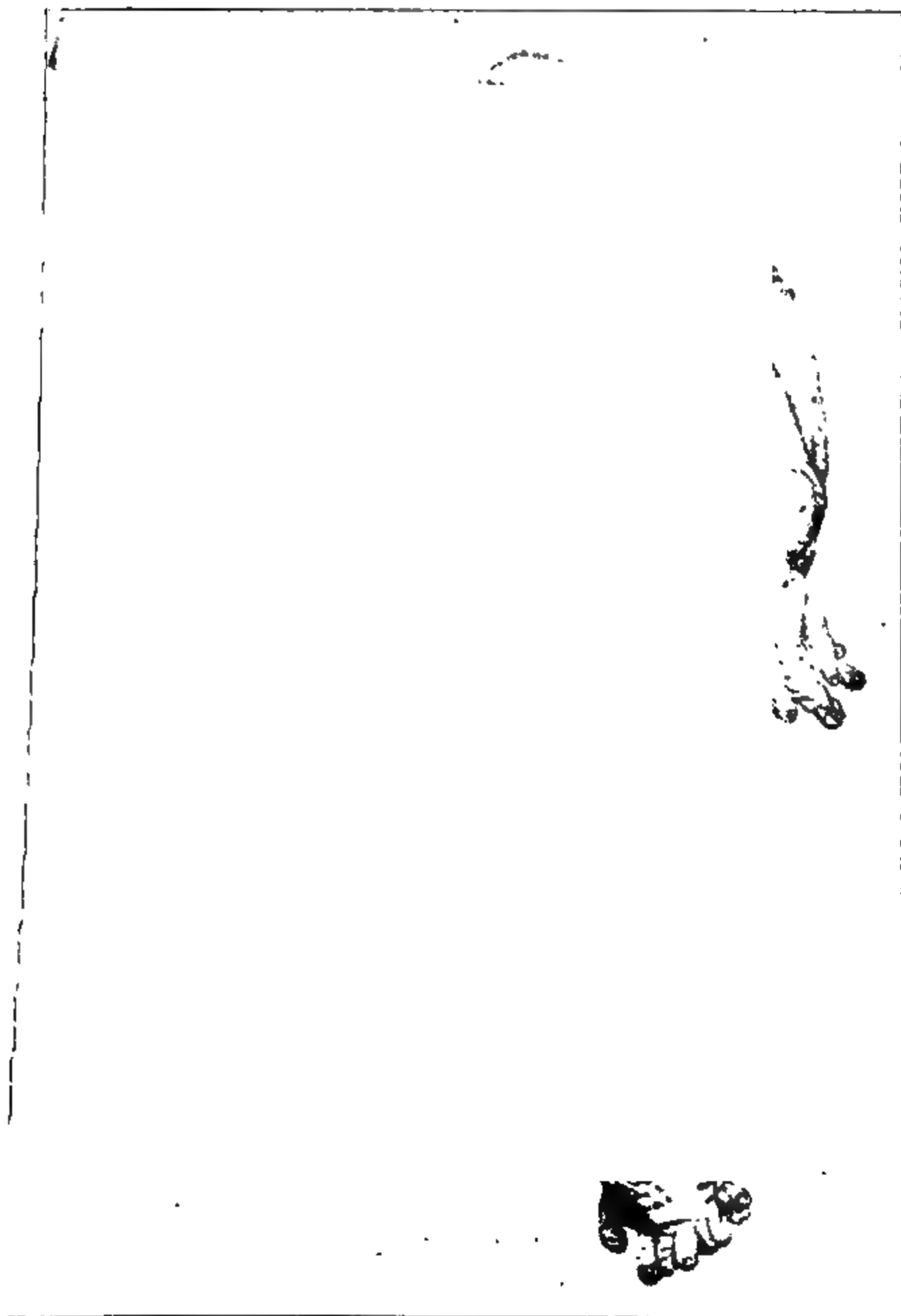


FIG. 1.—External view of the foetus.

words, that a measurement round the left side of the body, from the middle line in front to the middle line behind, would considerably exceed a similar measurement on the right side. This increase in size makes one suspect that part of the body of a parasitic foetus has been welded on to the left side of the primary one,—a suspicion which the study of the viscera bears out. The head and neck, viewed from the right side, has the usual appearance of an anencephalous foetus, but on the left side the head is elongated from before backwards, the auricle is small and ill shapen, and behind it there is a conical projection about a quarter of an inch long, with an aperture at its apex. This structure I was at first inclined to look upon as the mouth or nose, or both, of the parasitic foetus, because the limbs of this foetus are squeezed together and their flexor surfaces united; and it seemed to me that any opening which was in a line with the centre of these fused limbs should represent some median aperture of the foetus to which they belonged. Since I have had an opportunity of studying the osteology and myology, I have little doubt that this structure is the auricle of the parasitic foetus.

The posterior left lower limb resembles the posterior left arm in the opposing position of the two sets of toes, while the anterior left lower limb has the same shrunken characters that were noticed in the anterior left arm.

The male genital organs are well developed, and there are no traces of any belonging to the parasitic foetus.

OSTEOLOGY.

The skull is that of an anencephalous foetus, everything above the supraorbital ridges and the external occipital protuberance being absent.

The frontal bone is represented by the orbital plates, which are only partially complete, and the external and internal angular processes.

The three parts of the temporal bone are present, and on the right side are normal.

On the left side there is a process of bone, about $\frac{1}{4}$ in. long, and flattened from before backwards, situated behind the glenoid

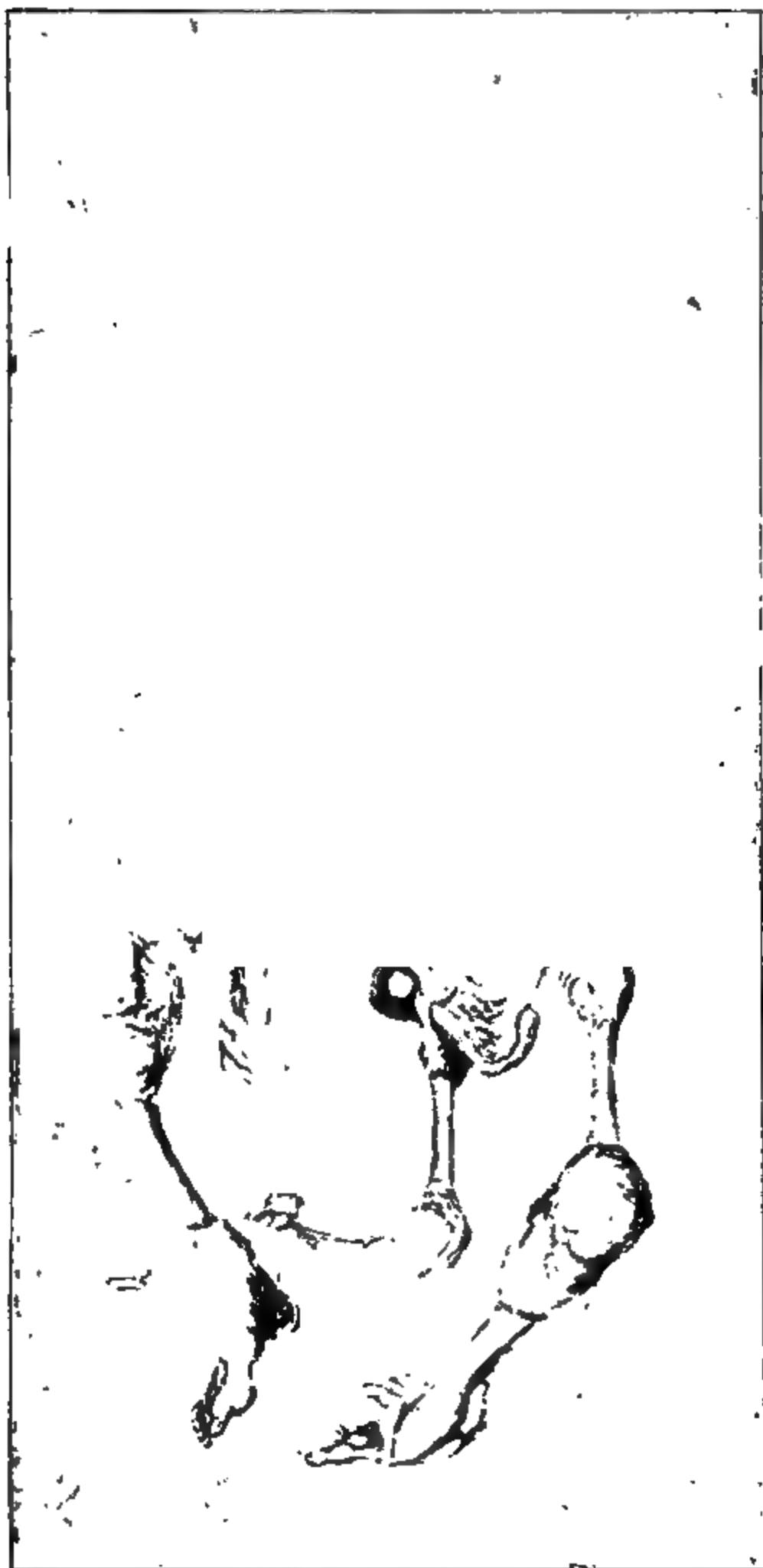


FIG. 2.—Skeleton.

cavity, and perfectly distinct from the post-glenoid process, which can be easily made out. This process, from its situation and appearance, I regard as the condyle and neck of a second lower jaw belonging to the parasitic foetus.

The upper part of the petrous bone on the left side is wanting, so that the internal auditory meatus has no roof.

The occipital segment of the skull is normal as far as the basi and exoccipitals go, but above the foramen magnum there is only a narrow transverse bar which represents the supra-occipital element.

Vertebrae.—The atlas is normal on the right side, but on the left it is absent. The other cervical vertebrae are normal on the right, but on the left the axis has two transverse processes, one behind the other. The dorsal and lumbar vertebrae are normal in number and appearance, and there is a well-marked left lateral curvature.

The Ribs are 12 on each side, the 11th being united by its cartilage to the 10th. On the right side they are united to the sternum in the usual manner. On the left their free ends are connected by a bar which corresponds to the longitudinal half of another sternum. Between these two sterna there is a gap of about $1\frac{1}{2}$ inch, which is filled with fibrous tissue in the recent state.

Upper Extremities.—The bones of the right side are perfectly normal. On the left side there are two upper extremities, the anterior of which is very ill developed, while the posterior consists of two fused arms.

The anterior left extremity is connected to the large (right) sternum by an ill-developed clavicle. The scapula has definite coracoid and acromial processes, but the ala is only represented by a small quadrilateral plate having the border, which ought to be the vertebral one, below. This scapula is continuous posteriorly with the coracoid portion of the corresponding bone of the posterior left limb. The humerus is normal in length, but only about half the diameter of the corresponding bone on the right side. The radius and ulna are also extremely delicate bones, but are not quite as long as those on the right. The hand, beyond its small size, shows nothing remarkable. The posterior left extremity is connected to the right sternum by a well-

developed clavicle. The scapula is normal except at its coracoid portion, where, instead of having a definite coracoid process, it is connected to the scapula of the anterior left extremity, as has already been described. It is a single bone, and shows no signs of division into two. The humerus has a longitudinal groove in front, and appears to be made up of two bones united by their flexor surfaces. There are two quite separate radii, both of which articulate with the anterior part of the lower extremity of the humerus, and are placed so that their flexor surfaces look

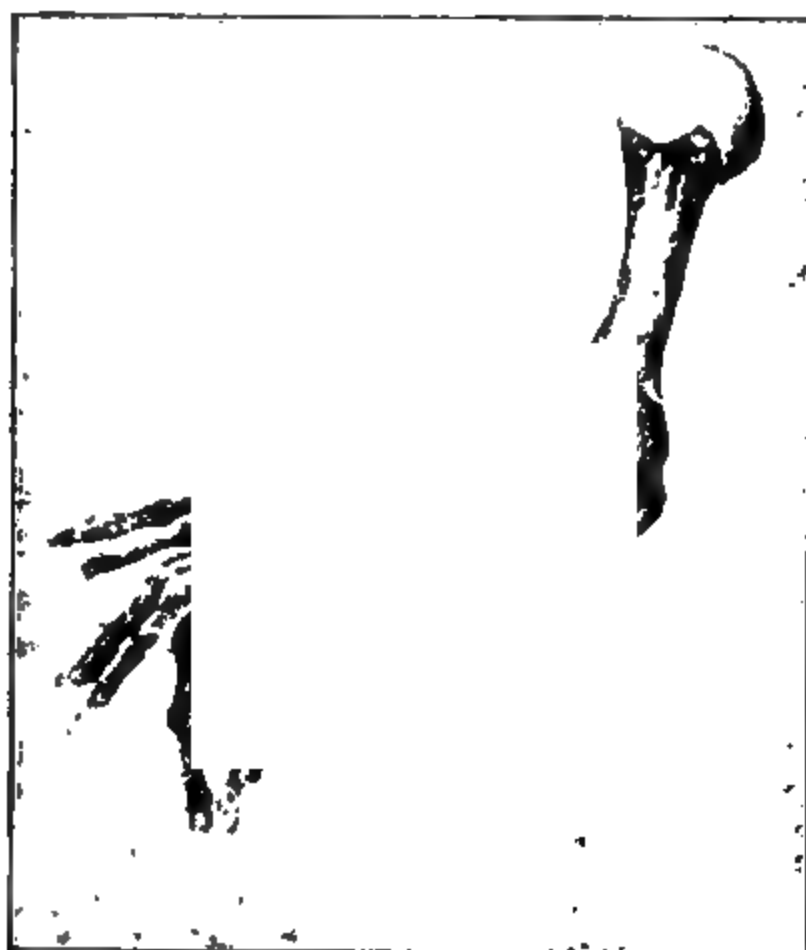


FIG. 3.—Bones of left posterior forearm.

towards one another, while their outer surfaces look forwards. The ulna is a single bone below, but above there are two olecranon processes, both of which articulate with the back of the lower end of the humerus. The dorsal surfaces of all the carpal bones can be made out on the left side of the double hand, but on the right side the ligaments render this impossible; it is quite evident, however, that there are two sets of carpal bones, the palmar surfaces of which are in contact. The bones of the two

thumbs are quite distinct from one another, and are normal. The metacarpal bones of the two index fingers are fused, but the phalanges are separate. The middle finger is only present on the left side of the hand; it has only two phalanges, the second of which is connected to the second phalanx of the left ring finger. There is no middle finger on the right side. The ring and little fingers are present, and their bones normal on both sides.

Pelvis.—The sacrum consists of six pieces, and is quite symmetrical. The right os innominatum is normal, except that it is pushed a little to the right, so that the symphysis lies in the same vertical line as the right sternum, *i.e.*, a little to the right of the median line. On the left side there are two ossa innominata, the anterior of which has the pubes and ischium well developed, but the ilium is placed horizontally, so that the iliac surface looks upwards and the gluteal surface downwards. The anterior part of the crest and the anterior superior spine are free, but the posterior part of the crest is continuous with the ischium, and possibly part of the pubes of the posterior left os innominatum. The acetabulum looks downwards and forwards. The other bones of the anterior left leg resemble those of the corresponding arm, being nearly normal in length, but of much smaller circumference than the bones in the right leg. The left posterior os innominatum is normal in its iliac portion by which it articulates with the sacrum. At the position of the iliopectineal eminence there is a short conical projection, which I regard as the aborted horizontal ramus of the pubes, the body of that bone being absent. The ischium is continuous with the crest of the left anterior ilium, as has already been stated. In front of the fused parts of these bones is a plate of bone which occupies the position of the descending ramus of the pubes. The obturator foramen is only represented by a notch. The posterior left femur, unlike the corresponding humerus, shows no signs of longitudinal division; the nutrient foramina, however, are on the inner side instead of behind. The tibia is single and longer than the fibula; it articulates with the tarsal bones only on the outer surface of its lower extremity. The inferior surface does not articulate with anything, but forms a pulley-like groove under which the tendons of the two tibiales antici join one another.

The nutrient foramen, as in the femur, is on the internal surface of the bone. The fibula is shorter and thicker than on the right side of the body; its lower end is somewhat expanded, and articulates with the tarsus to a much greater extent than the tibia does. The tarsus is everted and double, the two sets of bones being placed with their plantar surfaces in contact. On the inner side of the foot the two sets of tarsal bones are fused, but externally they are quite distinct. There is only one big toe, which does not seem to belong to one side more than to the other, the dorsal surface being directed inwards. There are two perfectly distinct sets of all the other toes, each of which consists of the normal number of bones.

MYOLOGY.

On the right side of the body the muscles are perfectly normal. A sternalis was looked for in connection with the anencephaly, but was not found on either side.

On the left side the anterior ill-developed arm and leg show very little trace of muscle, its place being taken by fibro-fatty tissue. There are, however, indications of the brachialis anticus and flexor muscles of the forearm, as well as of the hamstrings and gastrocnemius. On the extensor surfaces of both limbs there are no traces of muscular tissue.

The left side of the neck shows several muscular abnormalities. The trapezius is represented by two slips, the anterior of which rises from the ridge of bone which does duty for the supraoccipital, and is inserted into the outer part of the clavicle belonging to the left posterior extremity; the posterior slip rises from the region of the external occipital protuberance, and is inserted into the acromial region of the posterior left scapula. Deep to this last slip a muscle rises, which runs down to the superior angle of the left posterior scapula. It lies in the same plane as the rhomboids, and must, I think, be regarded as a *rhomboideus capitis*.

The *rhomboideus minor* is larger than usual, and rises from nearly the whole extent of the ligamentum nuchæ. The *rhomboideus major* is normal. The sterno-mastoid is double, and

consists of an anterior and a posterior muscle. The anterior has the usual origin from the sternum and from the sternal quarter, or less of the clavicle belonging to the left posterior extremity; it is inserted beneath and behind the anterior of the two auricles. The posterior sterno-mastoid rises partly under cover of the last from the inner third of the clavicle belonging to the left posterior extremity, and runs up to be inserted below and behind the posterior of the two auricles; its anterior border is covered by the last muscle. The spinal accessory nerve enters the posterior of these two sterno-mastoids close to its insertion, and sends some twigs through it to the anterior and superficial one; it is not continued on to the trapezius. Other twigs are derived from the cervical plexus. There is no omo-hyoid or subclavius on the left side.

The left posterior arm, as has been pointed out, consists of two arms fused on their flexor surfaces. The musculature is

L. PECTORAL

PECTORAL

FIG. 4.—Left posterior arm and forearm.

very much what would be expected under these circumstances. There are two perfectly symmetrical deltoid muscles, and between these lie two muscular slips representing the clavicular portions of two pectorals. The biceps is single, and in the mid line of the arm; it rises from the longitudinal furrow in the front of the humerus, just below the insertion of the pectoral muscles; below, it divides into two equal tendons which are inserted into the two radii. There is no coraco-brachialis. The brachialis anticus is double, the two muscles passing between the two radii and

fusing, to be inserted into the front of the ulna. The triceps is single, though broader than usual.

In the front of the forearm there are very few muscles. The two long supinators are symmetrical, and normal in their attachments. The pronator radii teres is only represented by a slight oblique strip of muscle which runs downwards and inwards, no trace of the opposite muscle being present. The flexor longus pollicis and flexor longus digitorum are represented by a single muscle on each side. The arrangement of these is curious. They rise from the middle of the front of each radius, and the two tendons cross to form an **X**; afterwards each of them divides into two, one of which goes to the thumb, while the other joins its fellow of the opposite side to form a broad tendon, which again divides for the two index fingers. Thus the right thumb is moved by the muscle, which rises from the left radius, and *vice versa*. There are no other muscles on the flexor side of the forearm.

On the extensor surfaces of the forearm the muscles are fairly normal. On the left, or outer extensor surface, the only abnormal points are the following:—The extensor secundi inter-

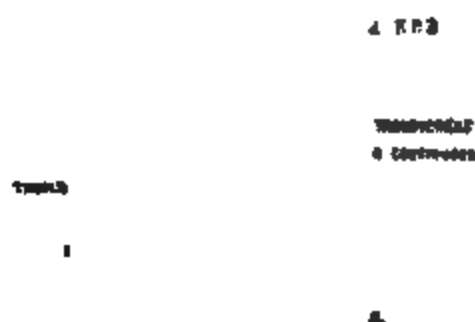


FIG. 5.—Fused hands from the radial side.

nodii pollicis, extensor indicis, and extensor primi internodii pollicis, have one common muscular belly, the tendon of which divides on the back of the wrist for its various points of insertion. The extensor communis digitorum and extensor minimi digiti are inseparable in their fleshy part. This divides later into two tendons, one of which goes to the fused middle and ring fingers, the other to the little finger.

On the right or inner extensor surface there is no extensor indicis, but the fused extensor communis and minimi digiti run to all the fingers. An abnormal muscle rises from the back of the radius deep to the extensor ossis metacarpi pollicis, and its tendon runs in a groove round the outer side of the lower extremity of this bone, to be inserted into the front of it just above the wrist-joint; it is possibly the extensor indicis which has missed its normal attachments. In the hand the short muscles of the little finger are well developed on each side, but those of the thumb are absent.

The abdominal muscles are normal on the right side. The left rectus rises from the aborted horizontal ramus of the posterior left os innominatum, and runs to the sixth, seventh, and eighth left costal cartilages; it is separated from its fellow on the right side by an interval of about an inch, in which the abdominal walls only consist of fibrous tissue. This fibrous tract corresponds to the part of the body occupied by the ill-developed anterior left arm and leg, and, like them, contains no nerves.

On the front of the thigh of the posterior left limb the muscles are fairly normal. The adductor longus and brevis rise from the rudimentary horizontal ramus of the pubes, while the adductor magnus and gracilis come from the vestige of the descending ramus. Both the adductor longus and pectineus are supplied entirely by the anterior crural nerve.

On the posterior (flexor) surface the muscles are not well developed.

The biceps rises from the fascia on the deep surface of the gluteus maximus by its long head, its short head and insertion being normal. The semimembranosus and semitendinosus are absent. Below the knee the leg presents two sets of extensor muscles, one of which is directed towards the right, the other towards the left. Unlike the forearm, there are no flexor muscles at all. On the right side the tibialis anticus ends in a broad flat tendon, which joins a similar tendon of the other tibialis anticus, to form a sling below the projecting internal malleolus; the inner part of this sling is attached to the base of the single first metatarsal bone. The extensor proprius hallucis and longus digitorum are normal, as is also the peroneus

tertius. The peroneus brevis rises from the upper half of the anterior surface of the fibula, and has its usual insertion.

The extensor brevis digitorum sends slips to the three innermost toes. There is no peroneus longus.

On the left side of the leg the tibialis anticus has exactly the same arrangement as the same muscle on the opposite side of the same leg. The extensor proprius hallucis and longus digitorum are normal. The peroneus brevis and tertius are fused

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FIG. 6.—Left dorsal surface of the double foot.

into one muscle, the tendon of which divides just before its insertion. There is no peroneus longus. The extensor brevis digitorum only consists of two slips for the hallux and next toe.

VISCERA.

The heart will be described later. The Thymus is well developed, the right lobe being the larger, and subdivided into two smaller lobes. The lungs are normal in lobulation and size. The liver shows an enormous increase in the size of the left lobe, which is nearly twice as large as the right; it pushes up the diaphragm as far as the left fourth rib, and occupies the extra space which is formed by the fibrous interval already described between the sternal extremities of the left ribs and the sternum. Its antero-posterior diameter is considerably greater than that of the right lobe, as is also its transverse. The anterior border is thick, while the posterior is quite thin. The urinary apparatus

shows distinct signs of the fusion of two foetuses, as there are traces of two bladders and of four kidneys. The right kidney is normal in position, but very large and distinctly lobulated; its upper end reaches up behind the right lobe of the liver to the diaphragm; its ureter is normal. The left kidney of the primary foetus is situated opposite the brim of the true pelvis; it is about half the size of the right one, and is of an irregular discoid shape. Its ureter emerges from the posterior flattened surface, and is

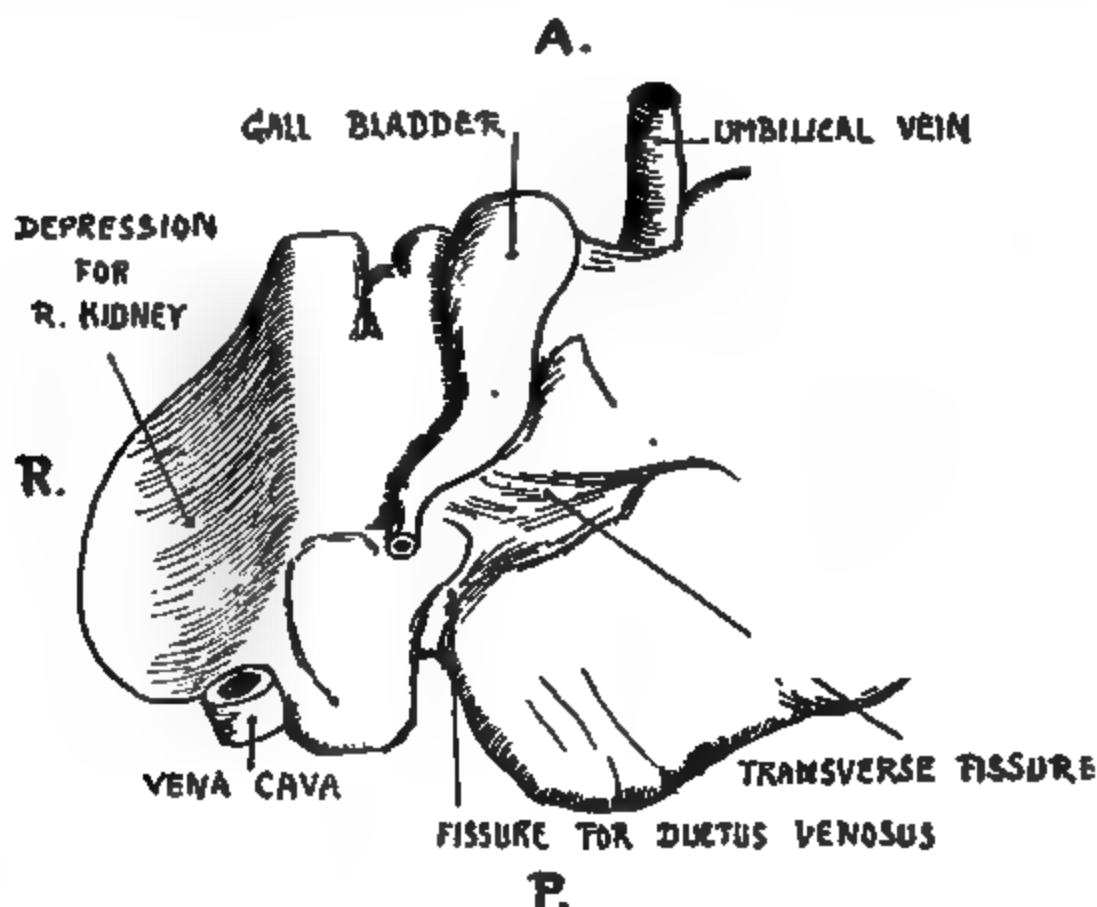


FIG. 7.—Under surface of the liver.

about an inch long; it opens into the base of the right or primary bladder. The two kidneys belonging to the secondary foetus are apparently not functional; the upper (left) one is flattened and small, its lower part being dilated into a small cyst. It is situated on the outer side of the left psoas, its upper edge being on a level with the lower edge of the large kidney of the right side already mentioned. The ureter comes from the upper part of the gland, and is dilated in the pelvic cavity. Immediately below the dilatation the duct is impervious, and here it is connected with a small triangular glandular mass, which I look upon as the representative of the right kidney of

the secondary foetus. Beyond this there is a very short dilated duct which communicates by a pin-hole aperture with the prostatic part of the urethra. The bladder of the primary foetus is normal in shape and position; it is continued up to the umbilicus by a patent urachus. Behind this, and a little to the left, is a conical and somewhat tortuous sac, having the base of

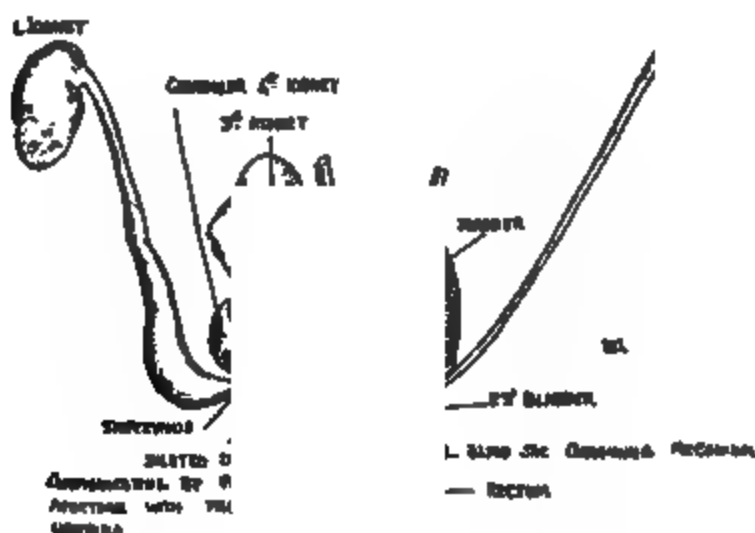


FIG. 8.—Urinary organs from behind.

the cone downwards, and being continued up at its apex by a narrow tube leading to the umbilicus; this structure, into which, as far as I can find out, nothing opens, I regard as the allantois and rudimentary bladder of the secondary foetus. No adrenal bodies were noticed.

The rectum is situated quite at the posterior part of the pelvis; between it and the last-named structure there is a blind sac distended with meconium, and communicating above with the rectum. In its floor there is a deep dimple, and I am inclined to look upon it as the impervious rectum of the secondary foetus.

NERVOUS SYSTEM.

The nerves of the right side of the body are normal.

On the left side no nerves were seen going to the anterior arm and leg, which probably accounts for their ill-developed condition. The brachial plexus is formed as usual by the 5th,

6th, 7th, and 8th cervical nerves, as well as by the 1st dorsal. Its composition differs very much from the normal arrangement, as would be expected when it is remembered that the limb consists of two extensor surfaces and no flexor surface; consequently there is no median or musculo-cutaneous nerve, while the musculo-spiral and circumflex are double. The arrangement of the plexus is shown in the accompanying diagram (fig. 9).

The right and left circumflex nerves are normal in their course and distribution.

The left musculo-spiral gives off a large external cutaneous branch in the spiral groove; this becomes cutaneous above the

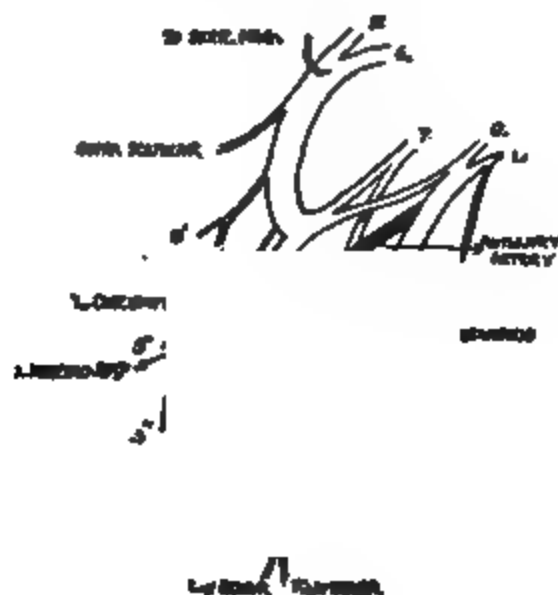


FIG. 9.—Brachial plexus from behind.

elbow, and supplies the whole of the skin of the outer side of the forearm. The musculo-spiral then divides into radial and posterior interosseous, after supplying the usual muscles of the arm as well as the biceps. The radial pursues a normal course, and supplies the skin on the dorsum of the left side of the fused hands as well as the back of the thumbs, index, and fused middle and ring fingers. A curious point in the distribution of this nerve is, that a branch crosses over to supply the palmar surface of the thumb and index of the opposite or right side of the fused hands, while a similar branch comes over to the corresponding parts of the left thumb and index from the right radial; there is thus a decussation of nerves on the radial side of the fused wrist.

The right musculo-spiral has the same distribution as the left, except that it sends no branch to the biceps.

The right and left ulnar nerves arise by a common trunk from the 8th cervical and 1st dorsal; a little below the middle of the arm the two nerves separate, and each passes behind its own condyle to enter the forearm, where it has its normal distribution, except that there is no flexor profundus digitorum to be supplied, and few, if any, deep muscles of the palm. The internal cutaneous nerve is single, and rises from the 8th cervical and 1st dorsal; it supplies the skin in front of the elbow joint, and for some little distance below.

The lumbo-sacral plexus on the left side is fairly normal, and it is not until the popliteal space is reached that any variations commence. Here the great sciatic divides into three branches, which are the right and left anterior tibials and the common musculo-cutaneous. The two anterior tibials supply their respective extensor surfaces, and end as usual by supplying the skin of the adjacent sides of the big and second toes.

The common musculo-cutaneous divides in the lower third of the leg, and supplies the two dorsal surfaces of the foot; from the outer of the two a branch is given off, which passes deeply between the two sets of tarsal bones and supplies the plantar surfaces of the toes. The internal saphenous nerve divides to supply the two dorsal sides of the single great toe.

THE VASCULAR SYSTEM.

The heart has a rather globular appearance, owing to the left ventricle being larger in proportion than the right. In other respects it is normal.

The pulmonary artery runs to its usual position on the left side of the ventral (ascending) aorta, and there gives off its two small branches to the foetal lungs. The main part of the artery is continued on as the ductus arteriosus, which, instead of taking its usual course, runs backwards round the left side of the trachea and oesophagus, arching over the left bronchus, and having the left recurrent laryngeal looping under it. When it reaches the back of the oesophagus, it joins the arch of the aorta to form the dorsal aorta.

The ventral aorta runs vertically upwards for a short distance in its normal position, in front and to the right of the trachea; it then gives off its three branches quite close to one another, and almost from a common trunk. The transverse arch of the aorta, instead of crossing in front of the trachea, runs backwards round the right side of that tube and of the œsophagus until it reaches the back, where it joins the ductus arteriosus to form the dorsal aorta. In its course it arches over the root of the right lung, and the right recurrent laryngeal nerve loops under it from behind forwards, or from right to left. The branches are given off in the inverse order to the normal.

The innominate and left carotid arteries are normal in their course and distribution.

The left subclavian artery, after giving off some minute branches to the anterior left arm, passes between the cords of the brachial plexus into the axilla of the posterior left arm, where it divides into two symmetrical branches; each of these,

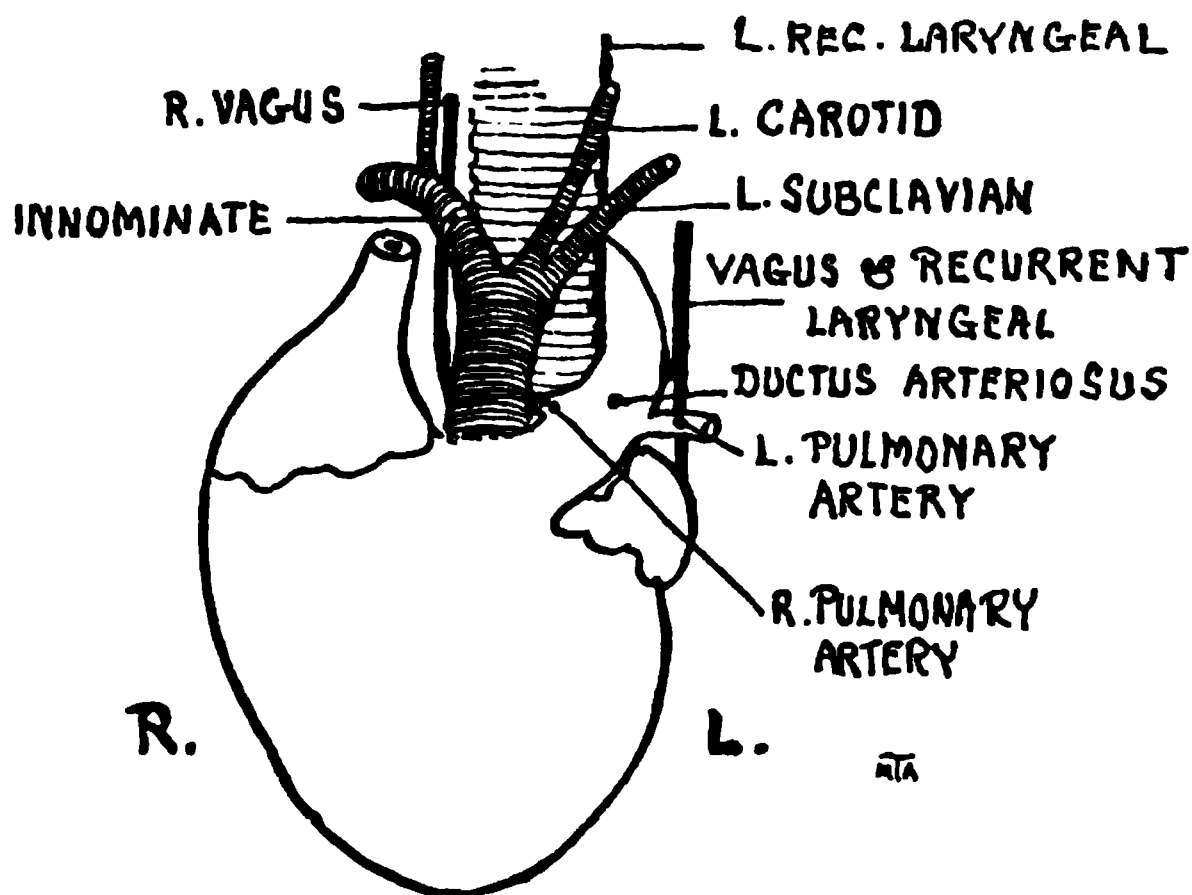


FIG. 10.—Heart and great vessels from in front.

after a short course, divides into two, to accompany the musculo-spiral and circumflex nerves of each side of this extremity. It will thus be seen that the vascular supply of the posterior left arm is effected through two posterior circumflex and two superior profunda arteries.

The two extensor surfaces of the forearm are supplied by two posterior interosseous arteries, which are continuations of the superior profunda.

The abdominal aorta is normal until its bifurcation, where it divides into a large right and a small left branch.

The large right common iliac divides into a large internal and a small external iliac, the latter of which pursues a normal course into the right leg. The large internal iliac, after giving



FIG. 11.—Great vessels from behind.

off branches to supply the whole of the pelvis, and some minute twigs to the anterior left leg, is continued up to the umbilicus as a single hypogastric artery.

The left common iliac does not divide into external and internal trunks, but is continued into the posterior left leg with the obturator nerve, and through the incomplete obturator foramen; soon after this it joins the long saphenous vein, which it accompanies down the inner side of the thigh and leg, giving off branches which do not seem to correspond to any of the named arteries of the lower extremity.

The veins of the posterior left upper extremity unite into a single cephalic vein, which runs up the front of the arm, lying in the median line between the two pectorals. It passes over the clavicle of this extremity and opens into the internal jugular of the left side, after receiving the external jugular.

The blood from the posterior left lower limb is returned by two veins, a femoral and a long saphenous.

The femoral comes from the deep parts of the thigh, and runs through Scarpa's triangle, to join the saphenous in the pelvis, thus forming the right iliac vein.

The saphenous commences close to the internal malleolus, and runs upwards, accompanying the artery already described,

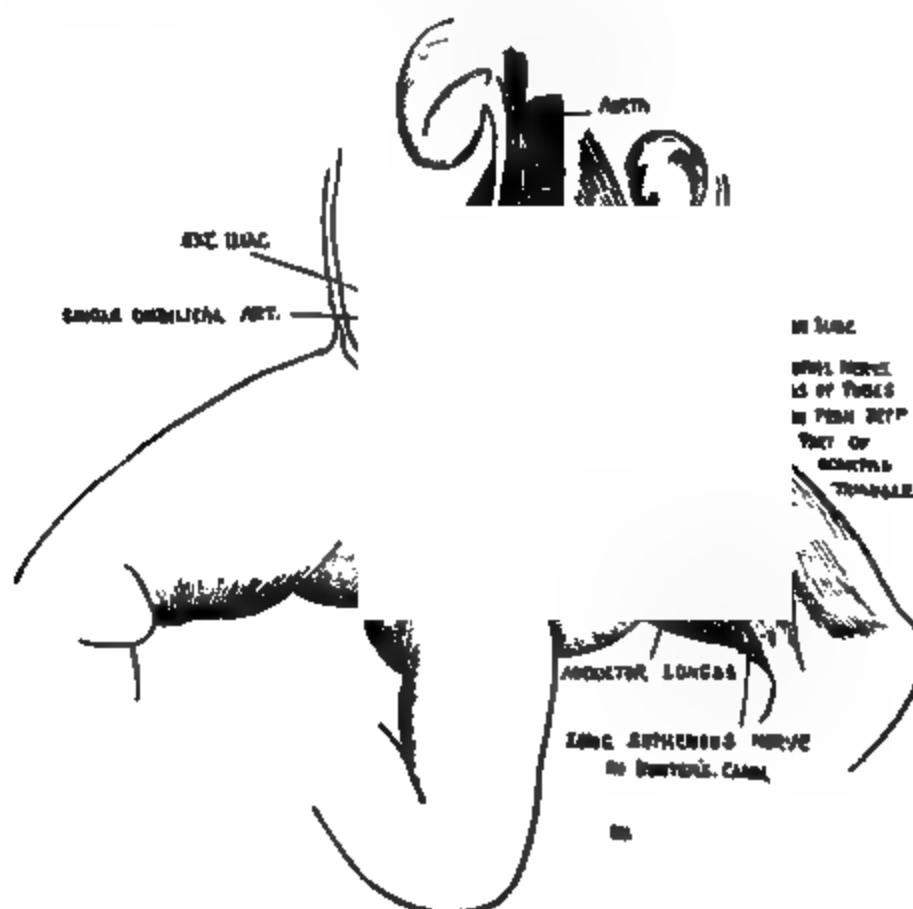


FIG. 12.—Abdominal aorta and its branches.

through the imperfect obturator foramen, to open into the iliac. The other veins of the body, as far as was observed, were normal.

With regard to other recorded cases resembling this, my study of the literature of the subject has not been very successful. Otto¹ treats fully of anencephaly, but there is no record of any case resembling this. Förster² figures a specimen of *dicephalus tribrachius*, in which the intermediate lower limb is double in its lower part, there being four toes on each side, with the big toe

¹ *Monstrorum Sex Humanorum Anatomica et Physiologica disquisitio.*

² *Missbildungen des Menschen*, Taf. vi. fig. 5.

single and common to both. The toes, however, are not opposed to one another. Ahlfeld¹ figures a double foot in which the toes are as opposed as in the present case. He also gives a picture



FIG. 18.—Inner side of the left posterior thigh.

of two fused arms from a dicephalus tribrachius, in which the ulna is single and the radius double.² The gap in the thoracic wall is also indicated by him in another case.³

Cleland⁴ lays down the law "that in cases of the supernumerary legs connected with the sacrum or the perineum, the legs developed as the proper legs of the animal belong originally to two different pelvises, being the right limb of a right pelvis and the left of a left." It has been suggested that the left anterior

¹ *Atlas zu die Missbildungen des Menschen*, Taf. xx. fig. 2.

² *Ibid.*, Taf. xi. fig. 4.

³ *Ibid.*, Taf. xxx. fig. 11.

⁴ *Proc. Phil. Soc.*, Glasgow, 1886.

aborted limbs and the right half of the fused limbs of this specimen represent the parasitic foetus; but the study of the bones, the kidneys, and the nerve supply makes me incline to the view that the fused left posterior extremities are the representatives of the parasitic foetus.

In conclusion, I wish to express my indebtedness to my friend, Mr M. A. Teale, for his kindness in preparing the greater number of the diagrams and sketches which illustrate this paper.

THE INFLUENCE OF A PREVIOUS SIRE.

By A. L. BELL, M.D., Dunfermline.

FOR generations past it has been believed and tacitly acknowledged by many honest observers that the progeny of one sire may be influenced in colour, formation, or other outstanding characteristic by a previous sire by which the mother has produced offspring, until, at the present day, it constitutes one of the fundamental beliefs that such is actually the case. For example, it is firmly believed by veterinarians and horse-breeders generally that if a thoroughbred mare have a foal by a work-horse or a stallion of a different breed from herself, she is spoiled for ever for breeding purposes, because, even to a thoroughbred stallion she will produce foals with a trace of impurity derived from the alien sire of her previous foal. There are several well-known cases often quoted in support of this belief. In the often quoted case recorded by Lord Morton, a seven-parts bred chestnut mare was served by a Quagga, the result being a hybrid foal resembling the Quagga, especially in having stripes on the body, this being only what was to be expected from the way in which the foal was bred. Next year, and two following years as well, the same mare was put to a black Arabian stallion, and the foals by this sire also showed traces of the Quagga "in the possession of body stripes and bars on the legs."¹ It seems strange that in this instance the bars *on the legs* should be referred to the influence of the Quagga, seeing that the Quagga, though striped *on the body*, has no leg-stripes, as the Zebra has.

In a second case, that of "Greyfriar," a race-horse got by "Hermit," a thoroughbred, out of "Perseverance," also a thoroughbred, his grey colour is said to have been due to the influence of a grey horse by which Greyfriar's dam had produced a foal the year before. But as Perseverance was herself a grey, having thrown back a long way to a grey ancestor, the case may be dismissed as valueless in reference to this subject.

¹ *Philosophical Transactions*, 1821, page 20. Darwin's *Origin of Species*, chap. v. page 129.

There are many other instances, more or less marked and recorded, with more or less conciseness and detail. For instance, M'Gillivray reports a case quoted by Dr Alexander Harvey in the *Aberdeen Journal*, of 28th March 1849, as follows: "A mare belonging to Sir Gore Ouseley was covered by a Zebra and gave birth to a hybrid. The year following, the same mare was covered by a thoroughbred stallion, and next year by *another* horse. Both the foals thus produced were striped, *i.e.*, partook of the characters of the Zebra."

This is, in all probability, the case of Lord Morton's chestnut Arab mare, which became the property of Sir Gore Ouseley after bearing a foal to a Quagga.¹ However that may be, the case is described in a slipshod fashion; no account of the mare's breeding is given by M'Gillivray; and there is another objection, to which I shall refer in criticising Lord Morton's case.

In a case referred to by Dr Harvey, a healthy woman was twice married; her first husband was scrofulous, as were her children. The second husband was perfectly healthy, and, so far as was known, had no trace of scrofula, yet the children born to him by the widow of the scrofulous husband were tainted distinctly with scrofula; and it is explained that the first husband not only tainted his own children, but impressed his taint on subsequent offspring not his own. But it is more probable, in this case, that the scrofula was a form of syphilis, or, as Harvey himself says, "the wife may have imbibed the virus in a *latent* form, and subsequently contaminated the children of the second husband."²

Harvey quotes also a case which was reported to him from the Island of Grenada, where certain ewes, themselves *white* and *woolly*, were served by a ram of a chocolate colour and having a *hairy* or coarse fleece. The year following they were served by a ram of their own breed, "but the progeny showed distinct marks of resemblance to the first sire." Besides the imperfect description of the "marks of resemblance," and the absence of any details as to the pedigree of the ewes, it is not made clear that the ewes were guarded from the intrusions of the "chocolate coloured ram" during the second breeding season. It is well

¹ See *Philosophical Transactions*, 1821, page 20.

² *Monthly Journal of Medical Science*, September 1849, p. 1136.

known to sheep-breeders that rams will travel long distances to fulfil their destiny with ewes in season.

There is yet another case which I have seen put down and heard related, but cannot tell who is the author. I refer to the instance of a white woman whose first husband was a negro, and who afterwards married a white man. She bore children to both husbands, and it is stated that the children of her second husband possessed negro characteristics due to the influence of the first husband.

To account for the influence of a previous sire, there are two theories put forward. *First*, that the spermatozoa of the first sire pass up the Fallopian Tubes to the ovaries and are absorbed by the unripe ova contained therein; and that these sperms, though of insufficient power to fertilise the unripe ovum, have yet sufficient power to alter the development of that ovum subsequently when it is fertilised by the spermatozoa of the second sire. I think it is admitted that the life of the spermatozoa is limited to a few hours or days at the longest, and that their powers of fertilising exist only during their life. When a spermatozoon is absorbed into an unripe ovum, it must surely die, so far as its individual existence is concerned, by becoming part of the ovum. It seems to me incredible that a dead sperm can exert any influence on the development of an ovum by which it was absorbed months before, unless the ovum possesses some special power of preserving, not only *its own latent power*, but the potency of the sperm on which it depends for the special growth intended by nature.

The *second* explanation of this supposed influence of a previous sire is, that there is an interchange of constituent parts of the foetal and maternal blood-currents. The exact amount of interchange between the two currents is not defined. We know that, on the one hand, certain constituents of the mother's blood connected with the nutrition of the foetus and oxygenation of the foetal blood, pass from the mother's blood to that of the foetus; and, on the other hand, that certain constituents of the foetal blood connected with the removal of effete and excrementitious products pass from the foetus to the maternal blood-current by means of the placenta. It is asserted that some part of the foetal blood enters the maternal circulation, not

perhaps as blood, but in one form or other; but, at any rate, in whatever form it may enter the maternal blood, it is asserted that the foetal element thus given up to the mother is kept by her and enables the mother to impress the characteristics of the offspring of a previous sire on subsequent offspring got by a different sire; that is to say, the first sire impresses his own offspring with certain of his own characteristics; the offspring of this sire impresses the mother through the blood-current; the mother, in turn, transmits the peculiarities of the first sire to her subsequent progeny by means of the blood element she is said to have received from her first offspring. Let us suppose for a moment that this influence of a previous sire exists in fact, and that the explanation here quoted is the correct one. We are driven, then, of necessity to the conclusion: 1st, That the foetus actually gives up to the mother, besides the waste products, some essential part of its blood, carrying with it the key to hereditary transmission, for it is impossible that the effete material passed from the foetus to the mother can carry any such power. 2nd, If so, then the blood of the mother must become more and more mixed with each succeeding pregnancy, and be liable therefore to impress on her offspring the peculiarities, not of *one* sire only, but of *every previous sire* to whom she has borne offspring. It is impossible adequately to comprehend where such a theory would lead us. It is fortunately not necessary now to discuss the ultimate ramifications of such a far-reaching and, as it seems to me, unnatural process, so utterly at variance with what we know of the definiteness of the physiology of nature.

The theory which was at one time advanced by M'Gillivray in the *Monthly Journal of Medical Science* for October 1850, that the influence of a previous sire was due to an actual transfer of blood from the foetus to the mother, cannot be entertained, because it has been proved beyond cavil or dispute that in ordinary circumstances, at least, no commingling of the maternal and foetal currents can take place, and that the two currents are not only distinct from each other at first, but remain so up to the very end of pregnancy. The two Hunters were the first to enunciate that there was no commingling of the two currents, the placenta acting as the means by which the blood of the foetus is oxygenated by *indirect* contact with the blood of the

mother, but also as a channel through which material for the building-up of the foetal tissues is supplied and effete matter removed. The Hunterian view of the structure of the placenta is that almost universally entertained. Dr John Reid and Professor Goodsir's researches, as well as those of Sir William Turner on the Structure of the Placenta, have proved that the connection of the two currents is indirect. In Majendie's *Physiology*, 2nd ed., p. 509, it is stated that "when a pregnant female dies of hæmorrhage, the foetal vessels remain full." In curious contrast to this statement is the case quoted by Dr Alexander Harvey in the *Monthly Journal of Medical Science* for October 1850 :—"A pregnant cow was seized with bleeding from the lungs; the bleeding continued till the cow died after a certain number of days"—the exact number of days is not stated. After death the foetal blood-vessels were almost empty like the mother's, and it was sought to argue that the connection between the two vascular systems was direct, and that draining the maternal vessels meant draining the foetal vessels as well. But it does not appear so remarkable when it is considered that the mother bled slowly to death, living for a number of days, in the course of which the foetus was practically starved to death, the blood being used up and changed in character, so that the vessels were empty just as they would have been after ordinary death from starvation. So that, in *ordinary* circumstances, the influence which is claimed on behalf of a previous sire cannot be derived through the foetal blood entering the maternal current as blood. But, though I have never seen such a case stated, I can readily understand how a *direct* connection might be brought about in certain abnormal conditions of the placenta. For example, if the thin membrane which ordinarily separates the foetal from the maternal blood were to give way, foetal blood, *as blood*, would undoubtedly mix with the maternal blood, *LOCALLY* at least. But we have no means of knowing whether, in such circumstances, the foetal blood thus introduced into the maternal current would be treated by the maternal system as an effete substance from the foetus and eliminated as speedily as possible, or would be taken into the mother's system as a matter of course, there to become part and parcel of the maternal blood current, or kept there for long afterwards, to act during a subsequent pregnancy as a kind

of ferment, giving to the mother's blood the power of impressing on subsequent progeny the characteristics of the foetus from which the alien element in her blood was originally derived. It was held by Prevost and Dumas that the blood corpuscles of the foetus, especially in the later stages, are larger and of a different shape as compared with those of the maternal blood, so that it is probable that in such circumstances, if the foetal blood enters the maternal current, it will be rapidly eliminated or changed without delay, till it exactly resembles the maternal fluid, losing its own individuality by merging into the larger and more potent blood current.

But though in ordinary circumstances no foetal blood, as blood, can pass into the maternal current, it is claimed that one of the constituent parts of the foetal blood, such as the serum, may do so and carry with it the potency which is claimed for it. But then it has never been demonstrated that the presence of foetal blood, *as blood*, in the maternal circulation has enabled the mother to hand on the peculiarities of the foetus to her subsequent progeny by a different sire. And it has certainly not been shown that the entrance of one of the constituent parts of the foetal blood can do so. If the presence of foetal blood, or some constituent part, really confers this power on the maternal blood, then the transfusion of blood from a foetus carried by another female, or, for that matter, from an alien *after birth* even, to the blood current of a female, would give this female the same power of transmitting the peculiarities of the alien whose blood she received by transfusion, to her progeny. It has been supposed that the process of hereditary transmission resembles the transmission by a female of acquired syphilis to her progeny. I cannot help thinking that the transmission of hereditary peculiarities is a very different process to the passing of the syphilitic poison from the mother to her offspring while *in utero*. The latter is merely a contamination of the foetus by the diseased mother, the process being on all fours with the passage of an active poison like strychnia from the mother's blood to that of the foetus. The transmission by heredity is on a much higher plane, and is as yet almost a sealed book, so imperfectly understood is the process. It has never been demonstrated wherein lies the germ or potentiality of hereditary transmission. It is manifest, how-

ever, that at any rate the spermatozoa and the ova have the power of handing down the characteristics of the male and female respectively which produced them, to the organism resulting from the union of these elements. Whether the blood, or one of its constituent parts, possesses the power of carrying the hereditary essence is, to say the least, very uncertain. It is far more probable that the male and female germs alone possess this power, and *that* quite independently of the blood of the male and female by whom these germs are produced. The blood, to all appearance acts as a nutrient pabulum, and there is every probability that the blood has no other function in life than simply to nourish the tissues and structures which are brought into contact with it.

It must be remembered that the claim, which is made by those who believe in the existence of such an influence from a previous sire through the blood, not only depends on the action of some part of the foetal blood which has been taken into the maternal blood current, but implies that this action is exerted in every case weeks, months, and years after the interchange which is said to take place has been accomplished. Short of absolute proof, which has never been adduced, I am constrained to conclude that there is not even a reasonable probability of the existence of such an influence, while no proof whatever has been brought forward to show that the blood in any case has the power of hereditary transmission. And yet the theory having been put forward as a positive fact, and accepted as such, any proof to the contrary must of necessity be negative proof, and it requires an immense accumulation of negative proof to overthrow even a mistaken theory; but this is away from the point at issue.

Though there is no direct communication between the vascular systems of the foetus and that of the mother, still the connection of the foetus with the mother is so intimate by means of the placenta, where the two systems are really dovetailed into each other, that any active poison introduced into either system will undoubtedly poison *both* organisms, provided the circulation continue long enough to carry the poison to both. If, for example, the blood of the mother be poisoned, that of the foetus will very soon be poisoned as well, provided always that the mother does not die before the poison has time to reach the placenta,

and through it the foetus. If the mother died very quickly, the foetus would not die from poison, but simply from suffocation. It was for a long time believed that "poisons injected into the umbilical arteries, although mixing with the blood on its way from the foetus to the placenta, do not affect the mother."¹ "I have often injected very active poisons into the vessels of the cord, but have never seen the mother suffer."² But this teaching was proved to be entirely erroneous by Sir William Savory.³ It is probable, in the light of Savory's experiments, that the injections of poison, as performed by Majendie and Williams of Liverpool, were so powerful that they killed the foetus almost instantaneously, stopping the foetal circulation and thus preventing the poison ever reaching the placenta, and through it the mother's blood.

Sir William Savory experimented on pregnant cats, rabbits, and dogs, and his experiments were not only complete and thorough, but quite conclusively proved that "such a poison as strychnia introduced into the chest or abdomen of a *live* foetus will certainly reach the blood of the mother, if the foetus live long enough to send the poison to the placenta, in which it is absorbed by the maternal blood." Savory put the pregnant mother under chloroform, opened the abdomen and uterus, and then gently withdrew one or more of the foetuses, taking great care not to injure the cord. He then injected a grain of strychnia in solution into the chest or abdomen of several of the foetuses and returned them to the uterus, which was closed by means of sutures. Convulsions set in almost at once in the foetuses, and, after an interval of from twenty-five to thirty minutes, these seizures commenced in the mother, who was kept steadily under chloroform, and death resulted from the poison in every case, though in one instance Savory put the mother at rest by anticipating the poison. An interesting fact was noted in one of these experiments: "the foetuses were alive after the mother expired, though they had been convulsed almost from the moment of injection." The explanation offered by Savory is that the mother died from asphyxia chiefly, but the foetuses, not

¹ Alison in *Cyc. of Prac. Med.*, vol. i. p. 83.

² Majendie in his *Compendium of Physiology*.

³ *Lancet*, Ap. 1858, p. 63.

being dependent on the action of the respiratory muscles, died more slowly from sheer exhaustion. In the last experiment on a pregnant bitch near full term, the foetuses were placed, after the injection of the strychnia, in a basin of water at a temperature of 100°, and quite clear of the mother; but the results were just the same, proving quite conclusively that poisons pass from the foetal circulation to that of the mother no less certainly than in an opposite direction.¹

The length of time elapsing between the introduction of the poison to the body of the foetus and the onset of convulsions in the mother bears out the conclusion that there is no direct connection between the two vascular systems, else the convulsions would have seized the mother almost immediately after the injection of the foetus, but these experiments go further, and show the *possibility* at least of some part of the foetal blood passing into the maternal circulation during gestation.

Unfortunately they leave untouched the great question to which I have already referred, as to whether the foetal blood or any part of it actually possesses the power that has been theoretically claimed for it.

The passage of such a poison as strychnia from the foetus to the mother seems to me to be analogous to the removal of effete or excrementitious matter in the same direction, the passage of carbonic acid, for example, from the blood of the foetus to that of the mother in the placenta.

I cannot believe that one sire can influence subsequent progeny, unless the most absolute proof be forthcoming, or *instances* be quoted of the most reliable nature, where the evidence is so indisputable that it cannot be gainsaid. I *question* the passage of any part of the foetal blood to the maternal current, and especially I disbelieve in the theory that the foetal blood possesses the power to impress the mother with the peculiarities of the foetus, so that she can transmit them to subsequent offspring. *In utero* the foetus occupies, relatively to the mother from a nutritive point of view, the position of a parasite, much the same as the relation of the mistletoe to the oak. When the statement is made that an unborn child can so impress the mother and change her blood, that she can after-

¹ *Lancet*, Ap. 17, 1858, "Savory on Poisoning the Foetus."

wards impress the characteristics of this same unborn child on her subsequent progeny, it seems to me as wild and impossible as if it were to be stated that a mistletoe could alter the development and characters of the oaks which will spring from the acorns produced by the tree from which the mistletoe drew nutriment and support.

The experiments of M. Flourens of feeding a gravid pig with madder, showed that the bones of the foetus were afterwards coloured.¹ But this does not prove more than was already known, namely, that certain materials contained in the mother's blood passed indirectly to the foetus.

But the most fatal objection to the recorded cases, so far as their decisiveness goes, seems to me to lie in the fact that in no single instance was the female *proved* to begin with. In the case of Lord Morton's mare, she was put to the Quagga and next year to the Arabian horse; but for anything we know to the contrary, this particular mare would have produced foals to this Arabian horse, showing stripes more or less defined, even though she had never been served by a Quagga. The mare was not pure bred, and this gives another loophole for suspicion. To make sure that the Quagga had actually exercised an influence on the foal got by the Arabian, the mare ought *first* to have born a foal to the Arabian, then one to the Quagga, and a third time produced a foal by the Arabian. The foals got by the Arabian, one *before* and the other *after* the introduction of the alien elements, could thus have been compared, and any difference of characteristic note observed at once. So also in the case of the Negro's widow (p. 261), to make even a reasonable probability of the matter, the woman ought first to have borne a child to (not a white man) but *the same* white man who was her second husband, then a child to the negro, and again a child to the white man, whose children, before and after the production of the half-bred child of the negro could then have been compared. Even then there would still have been disturbing elements which would prevent the acceptance of the theory as a fact, unless with very strong proofs which have not yet been produced. For instance, it is no uncommon thing for a white father and mother to produce certain of their family as dark and swarthy as any half-bred child. In

¹ *Annales des Sciences Naturelles*, 4th series, pp. 12 and 13.

the case as I heard it, there was no guarantee as to the paternity of the children of the second husband ; and in a case of this kind the greatest care would have to be taken to prevent any doubts as to the paternity, before founding on a single case, however interesting, a theory such as has been already referred to, at once so startling and so far-reaching in its consequences. Darwin states that "after twelve generations, the proportion of blood from any one ancestor is 1 in 2048, and yet a tendency to reversion is possessed by this remnant of foreign blood."¹

In the case of the hybrid from the Quagga and the chestnut mare, the mere existence of body and leg stripes and bars on the subsequent offspring, though unusual, proves very little, because it is known that all the varieties of the horse tribe have sprung from a common stock, and that the extreme diversity of the various breeds is the result of selection, natural and artificial, and of surroundings. Darwin says in this connection : "For myself, I venture confidently to look back thousands and thousands of generations, and I see an animal striped like a Zebra, but perhaps otherwise very differently constructed, the common parent of our domestic horse, of the ass, the hemionus, the quagga and the zebra."² He goes on, further, on the same page, to say that "there is a tendency in the young of each successive generation to produce the long-lost characters of ancestors, and this tendency, from unknown causes, sometimes prevails."

The stripes and bars to which so much weight has been given in Lord Morton's case, as showing the Quagga taint, are found, according to Darwin and other observers, in all breeds of the horse, including "a Belgian cart horse, with a double stripe on each shoulder and leg-bars, Welsh ponies, Norwegian cobs, the Kattywar horses of India described by Colonel Poole."³ It is further stated by Darwin that this undoubted tendency to reversion is most apt to take place in hybrids ; and as the chestnut mare was not pure bred, I do not think it is going far afield for an explanation to assert that the peculiarities of the second foal were due solely to reversion to an impure ancestor on the dam's side, as represented by the remaining eighth part of her breeding.

¹ *Origin of Species*, chap. v. p. 126.

² *Ibid.*, page 130.

³ *Ibid.*, page 128.

The same thing has been noticed among pigeons. If two members of different breeds of pigeons be mated together, there is a strong tendency to produce young birds with the blue colour and wing-bars peculiar to the Rock pigeon, from which all the varieties of modern pigeons have come. This is the case even in the hybrids of parents which, if mated with members of their own respective varieties, would breed true and pure, generation after generation.

A friend of mine who is a large breeder of thoroughbred horses, and one of the best judges of horses I have ever known, wrote to me, when I asked his experience on the subject of the Quagga foal theory, that "he went once a long way to see such a case, the owner asserting positively that the foal in his possession showed distinct traces of the ass, though it was got by a thoroughbred sire, the mare having produced a foal to an ass the year previous." It is absolutely impossible that this friend of mine could have missed any trace of the ass to be seen in the foal, however faint; and yet he told me in his letter that "the only trace of the ass about the place was the stupidity of the owner of the foal."

"Mulatto," the well-known prize thoroughbred stallion, was objected to when he was placed first at the North of England show some years ago, because his dam had previously been bred to a work-horse, and Mulatto himself was said to be impure on this account, and showed his impurity in the size of his hoofs, which were very large for a thoroughbred, so large as to be out of proportion to the thickness of the canon bones. But the sire of Mulatto, a pure thoroughbred named Highclerc, often got foals with large hoofs, his own being very big; and one horse called Golden Leaf, got by Highclerc out of a thoroughbred mare, I have myself seen, and he had undoubtedly extra large flat feet. In this case there was never any doubt or suspicion of a taint.

If it be possible for a sire to influence subsequent progeny not his own, it is fair to expect that he will be able to influence subsequent progeny which are his own; so that we ought to find, at least in a certain number of cases, the children of the same parents consecutively resembling more and more strongly their father; but so far as I have observed, the first child is just as apt to be like the father as any of the later children. Of course it

is evident that even when a sperm is absorbed by an ovum, it is possible that that particular ovum may be thrown off without being fertilised, and so in many instances the example may be lost ; but even making allowance for such an escape, there ought to be a sufficient number of marked cases to prove the influence of the previous sire beyond doubt.

EXPERIMENTS.

Unfortunately, I have not been able to experiment with such distinct varieties as the horse and the quagga, owing to the difficulty of procuring either an ass or a quagga as a sire ; but in the spring of 1885 I put a three-parts bred black maiden mare to a thoroughbred horse named "Peccaniny," and she produced a colt foal exactly the same as the sire in colour (a bright bay), and outstanding shape peculiarities. Even the white star on the forehead and the white hind foot were reproduced, so that I had apparently a mare that was particularly passive, so far as impressing her own peculiarities on her offspring was concerned. In all the foals which she bore I noticed the same feature, not one bearing the least resemblance to herself. I put her again, the first time she was in use, ten days after the birth of her foal, to another thoroughbred stallion named "Hamilton," whose sire, Gladiateur, won the Derby, and whose dam won the Oaks. The result was a dark brown filly foal the same colour as the sire, but having the white heel marks on the hind feet just visible and no more. The foal was like the sire in the peculiar shape and formation of the forelegs, which were too straight at the knees, forming what is known as "pig-knee." This foal had no trace of Peccaniny. Again, I put the mare to a thoroughbred called "Heatherbrae," a bright bay with a white star on the forehead, and one white hind leg. The result was a filly foal very dark-brown in colour, exactly the same shade of brown as Hamilton, the previous sire, but having both hind legs and one forefoot white, and a white blaze down the face. I thought that here was a case which might possibly owe the colour to the previous sire. But I have seen, since the birth of my foal, at least one other foal from a different mare, by "Heatherbrae," with exactly the same markings, white hind legs, white forefoot, and white face. It is more probable, therefore, that my foal obtained its colour and markings through its own sire from a near ancestor. A fourth time I put the mare to a stallion, this time an American hackney called "Planet," the result being a colt foal, brown, without white, exactly the counterpart of the sire. I intended to put the mare again to "Heatherbrae," and compare the first foal got by him with the last one, but unfortunately I was forced to destroy the mare owing to an accident.

From the fact that mares breed only once a year, I found it more convenient to make my next experiments with dogs, which are of quite

distinct varieties, and breed very evenly, especially among the older and purer breeds. I put aside the offspring of allied breeds, which are too apt to revert to a comparatively recent common ancestor, and I selected only dogs and bitches of known pedigree, and of pure and well-established breeds. I used, as the alien sire, only a dog of a variety as distinct and far removed from the bitch as possible, thus endeavouring to eliminate any chance of the result being due to community of ancestry.

1st. The first trial I made can hardly be considered a fair test, because the bitch, a pure bred prize Irish Terrier, Sheila VI., did not produce puppies by the Whippet to which I put her, so that her next litter of two dogs and three bitches by Champion Breadenhill were unlikely to be influenced in any case, as the spermatozoa of the Whippet were presumably sterile, and possibly incapable of reaching the ovaries.

2nd. In January 1890, I put a prize bred white English Terrier "Lively" to "Leeds Elect," a pure white dog of her own breed, and winner of many prizes. The result was two dogs and three bitches; one dog and two bitches pure white like the parents, and one dog and one bitch foul-marked round the eye and on the cheek, as is often the case in litters of this breed. In May following I put her to a prize bred Black and Tan Terrier "Captain." This breed, although named English Terriers too, is not only one of the oldest and most distinct breeds, but is far removed from community of ancestry with the white variety. The following period of rut I put the bitch again to "Leeds Elect," and the result was four dog-puppies all pure white. The alien was thus introduced between the litters by "Leeds Elect" and the puppies compared. Subsequently I put her to "Champion Eclipse," a pure white dog of her own breed, and got a litter of two dogs and three bitches, one dog and two bitches pure white, and the others foul-marked on the cheek and rump, a variety of foul-mark quite common in the breed.

3rd. Three years ago I put a maiden Irish Terrier, "Faire Lass," to a prize bred pedigreed dog of the same breed, named "Craigengillan," the result being a litter of seven pure bred puppies, which all died before three months, except one. The following "period" she was bred to a clumber Spaniel of pure parents, and produced three puppies, one dog and two bitches, flaked and marked with brown patches, with white faces, white rings round their necks, and in all respects like the mongrels they were. In the end of October of the same year 1891, I put her to a pure bred Irish Terrier of my own, the result being seven puppies, three dogs and four bitches, all pure bred and without flaw or any trace of the alien sire. Twice subsequently, without missing a "period," she produced puppies to the same dog, one litter of six, and the other of a single puppy, and in no instance did I find any trace of the Spaniel.

4th. In 1893, a daughter of "Faire Lass" had a litter of puppies to a pure bred Irish Terrier named "Barney." Next "period" she was served by accident by a fox terrier, and had a litter to him; the exact number I do not know. I bought the bitch thereafter, as the

owner believed her to be spoiled for breeding, and I put her again to "Barney," the result being one bitch puppy, which is perfectly pure bred, and resembles strongly one of the sisters from the dam's first litter.

The following two cases were related to me by the owners, though they did not come under my own eye. A cousin of my own bred his pedigreed collie to a pure collie dog and got a litter of eight puppies. Next time she was served by mischance by a brindled lurcher dog, and produced six puppies, all mongrels. Then she was bred, on my advice, to a pure bred collie again, but not the same collie as at first, as he was not available. The result was a fine litter of puppies as pure and free from trace of impurity as her first litter.

A Mr Hutton in this town keeps prize bred Pouter pigeons, one of the purest and best-known varieties. Some years ago he had the misfortune to have his best hen spoiled by being served by a "Tumbler" cock, another pure and well-defined breed. She had previously bred winners to a Pouter cock. Undeterred by the fears of breeders, who told him she would never again breed pure birds, Mr Hutton put her at once to a Pouter cock, and continued to do so for several seasons; and he assures me that never once did he have a single foul bird from that hen, or any trace of the Tumbler cock in subsequent nests. This hen bred two young hybrids to the Tumbler cock.

Instances of a white woman bearing children to a Negro and subsequently to a white man are of necessity extremely rare in this country, so that it is very hard to either prove or disprove the American case by producing a case of the same kind. I am glad to say, however, that as the result of numerous inquiries and patient waiting, I am able to put forward a case exactly similar. It is the more interesting and valuable that the offspring of the Negro and the white man, from the same white woman, can be seen and my facts verified by any one who cares to take the trouble.

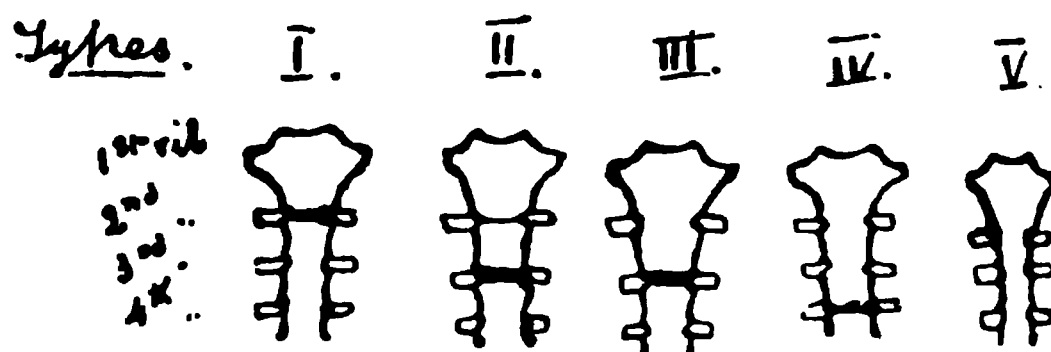
CASE.—A white woman, with brown eyes and fair skin, by name Christina Jeffreys, belonging to Markinch, in the county of Fife, bore a male child, on 1st November 1831, to a travelling show-man named Dusoos or Deseaux, a pure Negro. The child bears his father's name, and is at present working as a mason's labourer

in Cowdenbeath. He is an ordinary Mulatto, with strongly marked African features, black curly woolly hair and beard, touched with grey, and having a congenital deformity of the hands and arms. On the 5th July 1834, that is, 2 years and 9 months after the birth of the half-breed, the mother bore a child to a white man named Moyes. The child's name is Isabella Moyes, and she resides now in Markinch, where I saw and examined her very carefully on the 10th October 1895. She is a woman about 5 feet 8 inches high, with brown eyes, fair skin, thin lips, straight well-formed nose, longish face, with the features rather sharp, and coarse black perfectly straight hair; the ears are small and thin in substance. There is not the faintest trace of Negro blood in her form or features. I took the dates of the birth of these two children from the flyleaf of the mother's Bible, which Isabella Moyes kindly produced for my inspection.

A VARIATION THAT OCCURS IN THE MANUBRIUM
STERNI OF HIGHER PRIMATES. By ARTHUR KEITH,
M.D., F.R.C.S., *Senior Demonstrator of Anatomy, London
Hospital Medical College.*

MECKEL (1), Shepherd (2), Arbuthnot Lane (3), Turner (4), Dwight (5), and Paterson (6), have drawn attention to a variation that occurs in the form of the *manubrium sterni* of men and apes. The variation consists in the enlargement of the *manubrium* or *presternum* by the addition of the first meso-sternal segment. Stated in other words, instead of the joint in the sternum opposite the insertion of the second costal cartilages persisting, as in the ordinary human form (Type I., in the annexed table), the joint opposite the third costal cartilages persists, as is nearly always the case in Gibbons—the hylobatian form (Type III.). In young adults an intermediate form occurs, in which the joint opposite the third pair of cartilages is much wider than that opposite the second pair (Type II.). In the fully adult stage of such individuals, the manubrium sterni becomes of the hylobatian form. In very rare cases, only the joint opposite the fourth pair of cartilages persists (Type IV.). At late stages of life all the joints of the human sternum may be obliterated; this may happen at earlier stages of life in Gorillas and Orangs (Type V.). The prevalence of these various types of manubrium sterni is given in the annexed table.

The percentage with which this variation appears in Man is almost impossible to estimate—probably about 1 per 1000. It is of much interest to note, however, that at least three out of the nine cases recorded were found in dark-skinned people. It occurs amongst Gorillas at about 20 per cent.; Chimpanzees, 30 per cent.; Orangs, 1 per cent.; and in Gibbons about 80 per cent. It is a variation common to the higher Primates, but occurs with widely varying frequency in the different groups.



*Number of Individuals
examined: ¹—*

(1) Man, ²	Number ?	.	.	.	?	?	9	?	?
(2) Gorilla,	25	.	.	.	16	1	6	...	2
(3) Chimpanzee,	26	.	.	.	17	7	2	...	...
(4) Orang,	23	.	.	.	20	1	1	...	1
(5) Gibbons,	83	.	.	.	6	4	22	1	...
(6) Semnopithecus,	19	.	.	.	18	1	...	...	...
(7) Macacus,	16	.	.	.	16	...	...	...	...
(8) Ateles Geoffroyii,	?	.	.	.	...	...	1	...	...

Its occurrence in Man, I think, may be regarded as the persistence in a very few individuals of a simian, or, more properly, a hylobatian character. The fact that it apparently occurs more frequently in negroid people favours such a view. It is further favoured by one of Arbuthnot Lane's cases, in which a septal head to the biceps of the arm and a *chondro-epitrochlearis* muscle were also present in the same man. Both these muscles find their greatest development in Hylobates (Gibbons). There is also the further consideration that it is almost impossible to account for the present bodily structure and method of progression of Man, the Gorilla, and Chimpanzee, except by supposing that they have passed through a hylobatian period of existence. It is possible, however, that this variation is a character which may have been independently acquired by each group of the higher Primates.

The prevalence of this form of pre-sternum in Hylobates may be taken as evidence that it is for them more advantageous than the ordinary or human form. Its exact advantage is not very evident. Possibly it has to do with the great development

¹ The material from which the above table was compiled is contained in the following Museums:—South Kensington Natural History; College of Surgeons, England; University of Aberdeen; and University College, London. Besides having material of my own, I have used that recorded by Dwight, Deniker, Hervé, Heckel, Embleton, Traill, Tyson, Bischoff, Duvernoy, and Anderson.

² Besides the cases recorded by Meckel, Shepherd, &c., there is one in the Museum of the Royal College of Surgeons, England.

of the pectoralis major in Gibbons. That muscle plays an important part in their peculiar method of progression by brachiation. The greatly enlarged pre-sternum offers a wider surface for the attachment of the upper part of the pectoralis major. The tendon of the sterno-mastoid also reaches on the sternum to the level of the third pair of ribs. A large pre-sternum appears to have been attained in the Orang, which has a method of locomotion very similar to that of the Gibbon, by an enlargement of the manubrium without the addition of a segment of the meso-sternum.

The hylobatian form of pre-sternum is to be regarded, I think, as the ordinary manubrium with the first meso-sternal

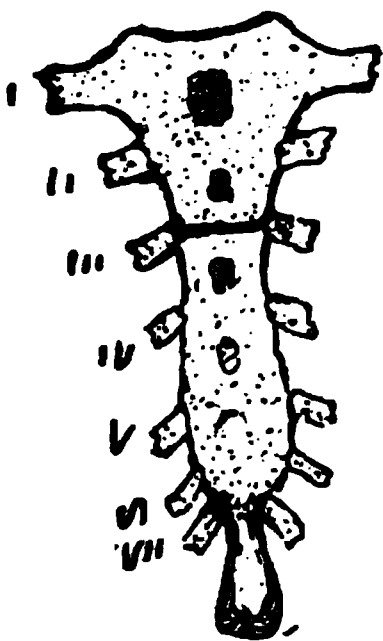


FIG. 1.—Sternum of *Hylobates pileatus* at birth. ♀

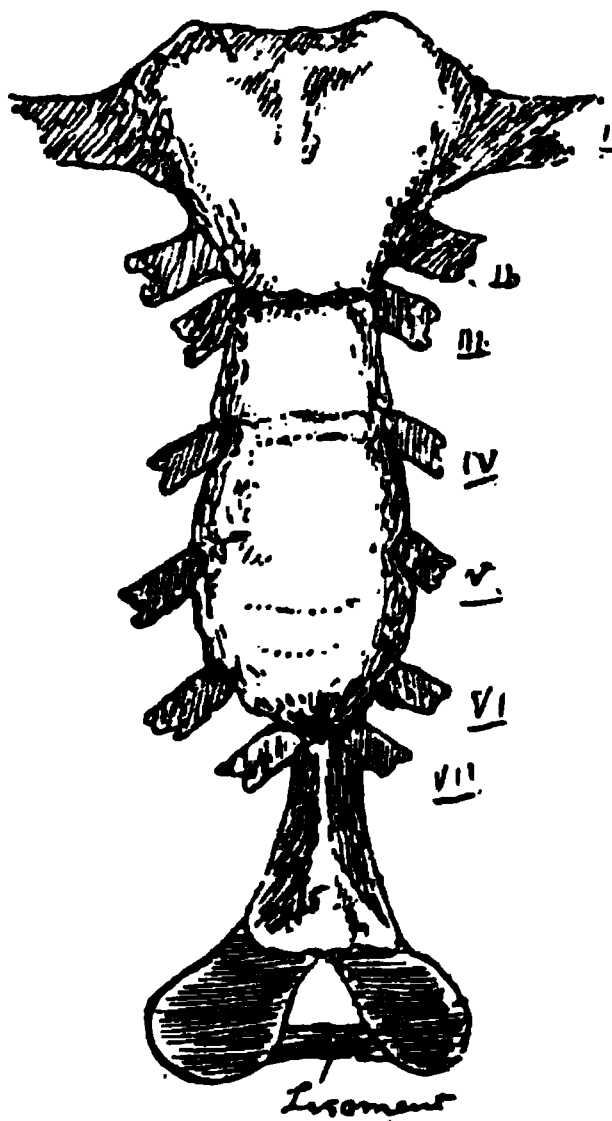


FIG. 2.—Sternum of *Hylobates* lar. ♀

segment added to it. In fig. 1 is represented the sternum of a *Hylobates pileatus* at birth. It will be noticed that four centres have appeared, and that the fibrous septum which lies, in the human sternum, opposite the insertion of the second costal cartilages, lies, in this one, opposite the third pair. The shifting of the fibrous septum from the level of the second to the level of

the third costal cartilages implies a very decided change in the formation of the manubrial joint.

According to Albrecht, and also to Ruge, the manubrium sterni is a composite bone made up of primal elements derived from many bones. Albrecht was of opinion that it always contained segments corresponding to ribs belonging to the seventh cervical vertebra. It is evident, if ribs belonging to that vertebra were present, that the manubrium, as in the hylobatian form, would have $2\frac{1}{2}$ pairs of ribs articulating with it on each side. In none of the cases recorded in the above table were seventh cervical ribs present. No explanation of this form of manubrium is derivable from that source. Arbuthnot Lane, however, suggested that there was a segment intercalated between the dorsal and cervical regions, and that the extra piece of the manubrium sterni in the hylobatian form belonged to the intercalated segment. There were really eight cervical vertebræ, and the eighth carried a rib. This theory was countenanced by the presence of a large strand from the tenth spinal nerve joining the brachial plexus. Such an addition to the brachial plexus, however, is not unfrequently found when there is no reason to suppose that there is an intercalated segment. The number of ribs, also, does not particularly favour Arbuthnot Lane's theory. Most frequently there is no increase in the number of ribs accompanying the hylobatian form of manubrium. In the case recorded by him there were thirteen ribs, eight of which reached the sternum. In two of the other cases recorded of Man there were eight sternal ribs, but only the usual number of twelve ribs in all. In the Gorilla and Chimpanzee eight sternal ribs occur more frequently in animals with a hylobatian form of manubrium than with the more usual form; but in Gibbons neither the total number of ribs, nor the number of sternal ribs, seem to be affected by the occurrence of the enlarged form of manubrium. In that genus the number of sternal ribs varies from six to eight, seven being the most common. This form of sternum, so far as my material goes, is not more prevalent in one species of Hylobates than in another.

In conclusion, I beg to take this occasion of acknowledging my indebtedness to the authorities of the South Kensington

Natural History Museum, and the Royal College of Surgeons' Museum, England, for the many liberties they have extended to me. I am also indebted to Professor Thane for references to literature dealing with this subject.

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- (3) ARBUTHNOT LANE, *Journ. Anat. and Phys.*, xix. p. 270, 1885.
- (4) TURNER, *Challenger Reports*, xvi. p. 78.
- (5) DWIGHT, *Journ. Anat. and Phys.*, xxiv. p. 536.
- (6) PATERSON, *Proc. Anat. Soc. Gt. Brit. and Ir.*, Feb. 1893.

FURTHER NOTES ON THE BRAIN OF *ORNITHORYNCHUS PARADOXUS*. By Professor Sir WM. TURNER.

SINCE the appearance of my account of the external characters of the cerebral hemispheres of *Platypus*,¹ much additional and valuable information on the brain of this animal has been published by Johnson Symington,² Alex. Hill,³ and G. Elliot Smith.⁴ By none of these anatomists, or indeed, so far as I know, by any previous writer, is a figure given of the brain as it lies in the head.

In July 1892 I received, through the courtesy of a former pupil, Dr E. J. B. du Moulin, residing at Dubbo, New South Wales, a well-preserved head of a *Platypus*, which, immediately after he had cut it from the body, had been immersed in rectified spirit, so that the brain was hardened *in situ*. It reached me in good order, and the dissection was arranged to show the brain as it occupied the cranial cavity, and without displacement of its constituent parts. The drawing from which the accompanying figure has been reproduced was made for me two years ago by my pupil, Mr G. A. Rorie.

The right cerebral hemisphere was 31 mm. long, the left the same. The lateral and superior cranial surfaces of each hemisphere were marked with branching vascular furrows, which began by a single relatively wide and deep furrow in front, immediately behind the olfactory bulb, branching repeatedly as it passed backwards, and the branches became smaller. At the anterior end the hemispheres had the smallest transverse diameter: they widened from before backwards, and reached their greatest width of 31 mm. immediately in front of the occipital condyles. At the posterior border of the hemispheres the occipital surface of the cerebellum was seen,

¹ *Journal of Anatomy and Physiology*, vol. xxvi. p. 357.

² *Ibid.*, vol. xxvii. p. 69, Oct. 1892.

³ *Philosophical Transactions*, 1893.

⁴ *Journal of Anatomy and Physiology*, vol. xxx., Oct. 1895 and Jan. 1896.

and at the posterior end of the longitudinal mesial fissure a glimpse of the tentorial surface was obtained; but the pineal body and optic lobes were entirely concealed.

The rhinencephalon projected in front of the anterior end of

each hemisphere, and a distinct fissure on each side separated it from the hemisphere; the projection itself was differentiated into two parts by a constriction. The more posterior division,

4 mm. long, is the part which has been previously figured by myself and others as the olfactory bulb; it was lodged in the olfactory recess at the anterior end of the cranial cavity; and it had a layer of grey matter on the surface. The part in front of the constriction, 5 mm. long, seemed as if the surface was formed of white matter, and was continued forward to the nose in a tubular prolongation from the olfactory recess. Apparently it was the commencement of the olfactory nerve.

SOME OBSERVATIONS ON THE TOPOGRAPHICAL
ANATOMY OF THE FOURCHETTE. By G. F.
BLACKER, M.D., F.R.C.S., *Assistant Obstetric Physician,*
University College Hospital.

(Read before the Anatomical Society, November 22, 1895.)

THE topographical anatomy of the female perineum is a subject upon which there exists a considerable amount of confusion in the minds of students; a confusion which is increased by the divergent statements and nomenclature to be found, even at the present time, in some of the chief text-books of anatomy.

The main question upon which anatomists differ is the relation of the fourchette or frenulum pudendi to the labia minora and labia majora; and further, its relation to the perineum proper and to the fossa navicularis. There are two views as to the anatomy of the fourchette: the first is, that it is a fold of skin uniting the posterior extremities of the labia majora; the second, that it is a fold of skin uniting the posterior extremities of the labia minora. Luschka was the first to call attention to the two varieties of fourchette; his description is as follows:—

“The posterior extremities of the nymphæ are not always arranged in the same way, as at one time they merge with the inner surfaces of the labia majora; at another time they unite with one another at the anterior extremity of the perineum. In this last case there is present a connecting band, ‘frenulum vulvæ seu labiorum,’ which almost universally has been called a derivative of the labia majora. But even in those cases in which the posterior ends of the nymphæ seem to cease, one can show by traction on them forwards a longitudinal fold which passes directly into the frenulum.”

Although Luschka¹ called attention (many years ago) to the two types of fourchette, yet it is quite the exception to find any mention of the second variety in most text-books of anatomy; an omission which is the more noteworthy when we consider the light thrown upon the real nature of the fourchette by this important, though less common arrangement of the parts.

¹ Luschka, *Anatomie des menschlichen Beckens*, S. 407.

The usual description of this region is given by Cunningham¹ in his *Manual of Practical Anatomy*, as follows:—

“The labia majora inclose an elliptical fissure, which is called the pudendal cleft. Within this fissure a slightly marked crescentic fold of integument, stretching between the hinder parts of the labia majora, will be observed. This fold receives the name of the fourchette or frenulum pudendi. Between the fourchette and the entrance to the vagina is a depression known as the fossa navicularis.”

Anyone who has taken the trouble to observe the anatomy of the female perineum will admit that this is a perfectly correct statement of the usual anatomical relations of the part.

A similar description is to be found in most anatomical works. Morris,² however, does not mention the fossa navicularis at all, while Ellis³ places it between the fourchette and what he terms the posterior commissure. His description is: “The labia majora are united in front and behind in the anterior and posterior commissures. At the back of the rima, within the posterior commissure of the vulva, is a narrow transverse fold of the integument called the fourchette or frenulum pudendi, and to the interval between the frenulum and the commissure the name fossa navicularis is given.”

The confusion that arises when the student passes from his anatomical studies with Ellis to his gynaecological, will be at once seen by the following quotation from the text-book of Gynaecology that is most commonly used, viz., that of Hart and Barbour.⁴ These authors, speaking of the labia majora, say: “Superiorly they form by their junction the structure known as the mons veneris, while posteriorly they are a mere fold of skin, known as the fourchette or posterior commissure.”

Of the fossa navicularis they say: “Usually the inner aspect of the fourchette is in contact with the outer and lower surface of the hymen. When the fourchette is pulled back by the finger, a boat-shaped cavity is formed—the fossa navicularis.”

¹ Cunningham, *Manual of Practical Anatomy*.

² Morris, *Human Anatomy*.

³ Ellis, *Demonstrations of Anatomy*, 1890.

⁴ Hart and Barbour, *Manual of Gynaecology*, 4th edit.

Besides Luschka, Henle,¹ Budin,² and Testut³ refer to the second variety of the fourchette.

Budin gives the following quotation from Sappey:—"The posterior extremities of the nymphæ do not usually pass the transverse diameter of the vulvar orifice, but lose themselves insensibly upon the sides of the vulva." Commenting upon this, Budin says:—"Such is the usual form of the labia minora in a certain number of women; in some, however, instead of stopping a little beyond the middle of the height of the vulva, the labia minora are prolonged backwards, turning towards the middle line, where they join one another.

"While in the usual condition the fourchette is formed by the labia majora, in the cases of which we are now speaking we find from before back, the vaginal orifice, the fossa navicularis, then the fourchette, constituted by the union of the labia minora. We have noticed this disposition in a certain number of white women, and we have also noticed it in a woman of colour."

There can be no doubt, from the descriptions of Luschka and Budin, that two definite varieties of the fourchette exist; one where it is apparently a band connecting the two labia majora, and another where it is formed by the union in the middle line of the posterior extremities of the labia minora or nymphæ.

With a view to determining how often these two varieties occur, I have made careful notes of the condition of the perineum and fourchette in 397 women attending my out-patient department.

Out of this number, in 49 I found it was impossible, owing to the extent to which the perineum had been torn in childbirth, to determine the anatomical conditions. Of the remaining 348, in 52, or 14·9 per cent., the fourchette was undoubtedly formed by the united posterior extremities of the labia minora; while in 292 it was a fold of skin apparently uniting the posterior extremities of the labia majora.

In 4 cases it joined the posterior extremity of the labium minus of one side, but did not reach that of the opposite side. Possibly this condition is the result of a tear of the perineum, and these 4 cases should be added to the doubtful ones. This

¹ Henle, *Handbuch der system: Anat. des Menschen*, 1874.

Budin, *Obstétrique et Gynecologique*, 1886. ³ Testut, *Traité d'Anatomie*, 1894.

leaves a total number of 344 women in whom the anatomy of the part could be determined with exactitude.

Of the 344, 45 were virgins. Of this number, the fourchette was of the type usually described in 39; while in 6, or 13·3 per cent., it was formed by the posterior extremities of the labia minora.

Of the remaining 299 women who were not virgins, in 253 the fourchette was of the usual type; while in 46, or 18 per cent., it was formed by the union of the labia minora.

89, or 35 per cent., of the 253 who had the usual type of fourchette, had had no children; while 11, or 24 per cent., of those who had a fourchette formed by the labia minora were childless.

Out of the 52 cases where the posterior extremities of the labia minora united to form the fourchette, in 19 they were definitely hypertrophied, while in the remaining 33 they were normal, except for their prolongation backwards.

From these observations it will be seen that in 14·9 per cent. of women, the fourchette is in direct continuity with, and is actually formed by, the labia minora. In such cases there is usually no trace of any second fold uniting the labia majora, nothing that the term posterior commissure could be properly applied to.

Personally, I have never seen any second fold; but Budin describes one case where there was a cutaneous fold joining the labia minora, and a second behind it joining the labia majora.

It will be noted that the percentage of parous women, viz., 76 per cent. as against 65 per cent., is rather higher amongst those with the fourchette formed by the labia minora than amongst those with the usual type; whether this indicates that childbirth has anything to do with the production of the former condition or not remains to be seen. I have not had sufficient opportunities of observing the condition present in young girls below the age of puberty to say whether this type of fourchette is ever present in them or not; so far I have not seen it.

It is contended by Savage,¹ Ballantyne,² Cullingworth,³ and

¹ Savage, *Anatomy of Female Pelvic Organs*.

² Ballantyne, *Edin. Med. Journal*, 1883.

³ Cullingworth, *Journal Anat. and Phys.*, vol. xxvii., 1893.

Coe¹ that the fourchette is a part of the labia minora, and has no real relation with the labia majora. Coe, in his description of the anatomy of the part, says:—"The labia minora are not lost, but reappear at the lower extremity of the vulva, where they are united by a thin muco-cutaneous commissure known as the fourchette or frenulum pudendi."

Savage refers to the fourchette as an apparent continuation of the folds comprising the nymphæ.

Ballantyne has pointed out that histologically the structure of the fourchette is exactly similar to that of the labia minora, and he calls attention to the interesting fact that a bad tear of the perineum seldom occurs in those cases where the labia minora are directly continued into the fourchette.

This latter observation of Ballantyne's I can confirm. Out of the 52 women in whom the fourchette was formed by the labia minora, 35 had had children, and of these only 3, or 8·5 per cent., had a definite tear of the perineum beyond the inevitable laceration that usually occurs; of 35 other women who had the usual type of fourchette, and who had had children, no less than 14, or 40 per cent., had a definite tear of the perineum.

These numbers are, no doubt, only approximately correct, and cannot be taken as representing the true percentage of women with or without a bad tear of the perineum, but they clearly show that there is a very considerable difference in the frequency with which bad tears of the perineum occur in the two anatomical types described.

Cullingworth, in a note on the "Anatomy of the Posterior Commissure of the Vulva," meaning by this the fourchette, says:—"Extensive clinical observation enables me to confirm the statement of Luschka, that it is the posterior junction of the labia minora, and not that of the labia majora, that constitutes the commissure. The labia minora are in some women deeply pigmented. It is in such women that the correctness of Luschka's observation can most readily be demonstrated, for the pigmentation is continued across the anterior boundary of the perineum. But, apart from this, if any one will take the trouble, in an adult virgin, to draw the labia minora gently upwards, taking one between each thumb and finger, he will find that they

¹ Coe, *American System of Gynecology and Obstetrics*, vol. i.

pull on the fourchette, and draw it upwards too, and he will see that the structure is in all respects similar and continuous. No such effect is produced on the fourchette by upward traction upon the labia majora, and I am not aware of the existence of any evidence in favour of the still too common statement, that the posterior commissure of the vulva is constituted by the labia majora."

These observations of Cullingworth can be readily verified, and the continuity of the labia minora with the fourchette can be shown, not only by traction on the labia minora forwards, but almost better by traction on the fourchette backwards. If the tip of the finger be inserted into the fossa navicularis, and traction be made in the direction of the anus, a small fold of skin will be made evident, passing from the extremities of the fourchette to the posterior extremities of the labia minora.

Ballantyne's account of the histology of the fourchette, together with Cullingworth's statements, appear to me to be strong evidence in favour of the view that the fourchette is really a part of the labia minora; while the further fact that, in about 15 per cent. of all women, the two are directly continuous, would tend to show that such an arrangement is something more than a mere variety.

This form of fourchette, occurring as it does in virgins, is certainly not merely a result of the changes that occur in the external genitalia in connection with childbirth. It appears first, as far as my observations go, after the age of puberty, and is associated with the development of the external genitalia that occurs at that period of life.

It would be well if the use of the terms anterior and posterior commissure could be entirely given up.

The anterior commissure is better called the mons veneris; and the term posterior commissure, applied as it is by some authors to the fourchette, and by others to the perineum, is not required. The posterior extremities of the labia majora blend with the perineum, and are not really united by any commissure other than the fourchette; but the use of the name posterior commissure for this structure only tends to lead to confusion, more especially if we are to regard the fourchette as really a part of the labia minora or nymphæ.

THE TRUE CAPSULE OF THE KNEE-JOINT.

By HUBERT HIGGINS.

(Read before the Anatomical Society, November 22, 1895.)

ON carefully cutting through the fibrous expansions of the two vasti, a multilocular bursa is exposed between the accessory and the true capsule; on either side these bursal intervals can be easily enlarged with the finger. The true capsule may be easily defined by carefully dissecting and removing the accessory capsule.¹ The two capsules are connected by some loose connective tissue, which is densest between the lateral ligaments and the ligamentum posticum Winslowii. The true capsule is a well-defined loose membrane attached to the margins of the articular surfaces of the patella, tibia, and femur. From the margins of the articular surfaces of the condyles it is reflected for about a centimetre on to the non-articular surface of the bone; on either side the attachment inclines upwards on the deep aspect of the lateral ligaments; posteriorly it is attached to the margins of the articular surfaces; in front it is attached to the borders of the internal and external articular surfaces of the tibia, and the interarticular space as far back as the tibial attachment of the anterior crucial ligament, whence it passes over the front of the crucial ligaments to their femoral attachments close to the articular surface. Posteriorly and mesially the membrane is attached to the margins of the articular surfaces of the femur and tibia; between these attachments it envelops the crucial ligaments. There is a *cul-de-sac* lined with synovial membrane covering the hinder surface of the femoral attachment of the anterior crucial ligament; this *cul-de-sac* is opened out when the joint is flexed. The true capsule is attached to the upper and lower borders of the semilunar cartilages in

¹ I look upon the accessory capsule as being all the ligaments derived from extracapsular structures, with intervening tissue distinct from the true or synovial capsule—viz., the lateral ligaments, the ligamentum posticum Winslowii, and the expansions of the vasti. The term "true capsule" has been used without any prejudice to its morphological origin.

such a way as to leave exposed the circularly-disposed fibres which form their basis; between the lower border of each semilunar cartilage and the tibia the true capsule forms the coronary ligament.

The capsule is a fairly thick, well-defined membrane, except where it invests the sub-patellar pad of fat and the crucial ligaments. There are strengthening fibres, some of which are disposed in a triangular fashion passing from the attachment of



The true capsule of the knee-joint, the accessory capsule and the sub-patellar pad of fat removed. (1) Internal semilunar cartilage; (2) Coronary ligament.

the lateral ligaments downwards and forwards, while others are vertically disposed fibres, lying deeply to the lateral ligaments.

In about two per cent. of cases there is no connection between the synovial cavity and the sub-crureus bursa. There is usually an opening varying from a complete obliteration of the septum to a small ovoid deficiency admitting an ordinary lead pencil.

On its superficial surface the tendon of the popliteus enters the true capsule on a level with the short external lateral ligament;

the capsule may or may not be adherent to the superficial surface of the tendon as far as its femoral attachment. The deep surface of the muscle, where it becomes tendinous, is usually intimately adherent to the walls of a bursa, which extends downwards under the muscle to the lower limit of the superior tibio-fibular ligament. This bursa communicates freely with the synovial cavity of the joint.

The ligamentum mucosum, when represented by a septum, consists of two layers which split to enclose the crucial ligaments, and are attached above and below to the periphery of the articular cartilage of the tibia and femur. The septum is bounded above by a free, lunated margin, attached anteriorly to the lower border of the patella, and posteriorly to the lower and mesial margin of the trochlea.

I should look upon the more ordinary form of the true capsule as the remnant of the two capsules limiting the tibio-condylar articulations, the anterior part having become obliterated, while the ligamentum mucosum represents the mesial and anterior parts of the capsules.

It is easy to demonstrate that the anterior cornu of the internal semilunar cartilage, and the posterior cornu of the external semilunar cartilage, are outside the true capsule to the extent of a centimetre; the other cornua are outside to a much less extent. These facts, taking into consideration the extracapsular dispositions of Humphry's and Wrisberg's ligaments respectively, might be used as arguments of an extracapsular origin of the semilunars, if there was any embryological confirmation of the view.

THE GENICULATE ARTICULAR SURFACES OF THE FEMUR AND TIBIA. By HUBERT HIGGINS, *Demonstrator of Anatomy, University of Cambridge.*

(Continued from page 582, vol. xxix.)

PART II.—THE TIBIAL GENICULATE ARTICULAR SURFACES.

THE upper extremity of the tibia is inclined backwards at an angle of 71° with the shaft (average of 40). Each articular surface for the condyles, separated by an interarticular area, presents for examination a spine, an internal and an external border.

Average Measurements of Tibia.

Length of bone,	36.01
Breadth of upper extremity,	7.45
Artero-posterior (at level of tubercle),	5.65
Artero-posterior (above tubercle),	4.86
Oblique (from front of internal artie surface),	6.85
Oblique (from front of external artie surface),	7.21

The *internal articular surface* projects about 75 c.c. further forward than the external. It is almost always more or less biconcave and ovoid in shape. The following are the average measurements:—

Antero-posterior,	4.60 cm.
From spine to periphery (transverse),	3.51 „
From spine to centre of anterior border of the inter-articular space,	3.15 „
From spine to anterior extremity of articu- lar surface,	2.48 „
From spine to posterior extremity of articu- lar surface,	2.71 „

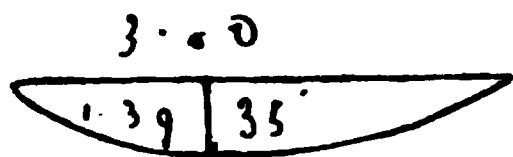
In examining the conformation of the surface from before backwards, it is found that for about 1.00 cm. it is usually slightly convex or plane and then concave for about 3.40 cm. The average transverse diameter is 3.50 cm.; for about 2.00 cm.

the surface is concave horizontally; mesially the concavity is almost on a vertical plane, culminating in the spine.

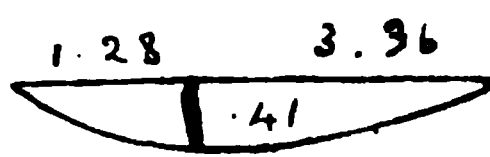
The *internal border* in front is usually almost pointed and depressed, it may be rounded. Behind, it is rounded and convex, pointed or very slightly convex.

The Internal Articular Surface.

Transverse Curve.

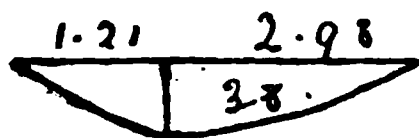


Antero-Posterior Curve.

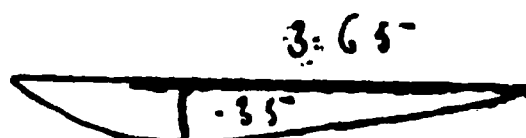


The External Articular Surface.

Transverse Curve.



Antero-Posterior Curve.



The remainder of the border is more elevated, giving the internal articular surface its cup-shaped appearance. It may be angular at the junction of the external and posterior limits.

External Border.

(1) In front of spine. This border is always markedly elevated, and projects almost directly forwards; about 1.70 in front of the spine there is very commonly a tubercle (about .70 cm. in width); from this the border inclines gradually downwards to the anterior extremity of the articular surface, which is somewhat raised above the rest of the articular surface. The tubercle serves for the attachment of the anterior crucial ligament, with which it forms a smooth curved support for the femur in full extension.

(2) The spine is usually flattened from side to side, and sharp. Its average elevation, from the depth of the concavity of the articular surface, is about 1.50 cm., and its average antero-posterior measurement 1.00 cm.

(3) Behind the spine. The border is slightly above the level of the articular surface, and runs directly backwards, or backwards and a little inwards.

The posterior edge of the spine is generally vertical, but it may be inclined obliquely.

The External Articular Surface.

The curves from before backward are so variable that it is advisable to divide the surface into three parts. The anterior third is more or less convex for about 1·20 cm. ; in 30 per cent. it may be plane or even concave. The middle third is usually concave; it may be plane or convex. The posterior third is almost always smooth and markedly convex, but it may be plane. In about 4 per cent. of specimens the entire surface may be slightly concave from before backwards, and in about 8 per cent. convex.

The spine forms the summit of a more or less inclined plane running either directly outwards or backwards and outwards; the plane is frequently interrupted by a central shallow concavity, or more frequently has a plane or slightly concave edge.

Internal Articular Surface.

Antero-posterior,	3·97
From spine to periphery (transverse),	3·26
Spine to centre of border bounding interarticular space anteriorly,	2·93
From spine to anterior extremity,	2·83
From spine to posterior extremity,	2·71

Internal Border.

(1) In front of spine it usually runs outwards and forwards, and is about 2·00 cm. in length. It may be concave from the spine to the anterior extremity, but more commonly it is on the same plane as the adjacent articular surface for about the anterior third, which is occasionally grooved. The external semilunar cartilage is grasped between this groove and the femur in full extension.

(2) The spine is sometimes rounded, more often a sharp projection, being in about 2 per cent. of cases as much as ·70 cm.

above the centre of the articular surface; its average antero-posterior measurement is .70 cm.; it may be as much as 1.10 or as small as .30.

(3) Behind spine. This surface rises to occasionally the same height as the spine, and is usually surmounted by a more or less prominent tubercle of varying size and shape, about 1.00 cm. from the spine; the border then descends somewhat abruptly to the level of the posterior extremity. This elevation helps to arrest rotation in full flexion.

The External Border.

For about 1.00 cm. from the periphery of the border the surface is very slightly elevated, and usually plane, with an occasional indication of a shallow groove for the semilunar cartilage.

Interarticular Surface.

(1) In front of spines. It is bounded anteriorly by a slightly convex roughened and tuberculated margin, and usually presents a marked depression immediately internal to the external articular surface; from this the surface rises to support the outer part of the adjacent elevated part of the internal articular surface.

(2) Interspinal area. There is a strong ridge of bone running forwards and inwards from a little behind the external to the internal spine.

(3) Behind the spines the surface is inclined downwards and internally from the interspinal ridge, and the adjacent elevated internal border of the external articular surface, to a roughened depression, bounded internally by an almost vertical ridge, limiting the internal articular surface. Posteriorly, there is a smooth, vertically striated edge, cut backwards and outwards concave from side to side.

Interval between Articular Surfaces.

In front of spines,	.	.	.	.	2.61
Between spines,	.	.	.	.	1.13
Behind spines,	.	.	.	.	1.91

URINARY CALCULI: THEIR FORMATION AND STRUCTURE.¹ By Sir GEORGE MURRAY HUMPHRY, M.D. Cantab., F.R.S., &c., *Professor of Surgery in the University of Cambridge.*

HAVING commenced my medical career as an apprentice at Norwich, and as a pupil at the Norwich Hospital, my thoughts were early directed to the subject of urinary calculus, particularly in its practical bearings; and for many years subsequently I had much experience in the treatment of stone in Addenbrooke's Hospital. It is not, however, my intention to take you at any length over the well-trodden ground of the treatment of this malady, but rather to discuss for a short time the structure and mode of formation, or building up, of stones in the bladder and some of the forms they assume, matters which, I think, have some interest and some difficulties, and which have not received much attention. I do not mean the microscopical constitution or the chemical composition, but rather the more obvious physical structure, of calculi. For this purpose I have gone, more or less carefully, over nearly all the collections in London as well as that in Norwich, and that in our own museum here. I do not wish by this to raise your expectations of what I have to say, for I must confess to being not very proud of my results in ascertaining the causes of the peculiarities which some calculi exhibit, and I am reluctantly obliged to leave many of these points to the more fertile reflections of yourselves and others.

Let me first draw your attention to a few remarkable specimens. I show you here one of the largest calculi which has been found in the human bladder, and which presents some points of historic and collegiate, as well as of clinical, interest. According to an account of it by Dr Heberden given in the *Philosophical Transactions*² it weighed thirty-three ounces and three drachms, and was taken after death from the wife of a locksmith at Bury St Edmunds. It was shown to Charles II. at one of his visits to Newmarket, "when at least half an ounce was broken off before the king to show him that it was formed in the manner animal stones usually are." It was of an "oval shape, flattened on one side and its surface smooth." The specific gravity was 1.75. It was presented to Trinity College, Cambridge, by Mr Samuel Battely, Member of Parliament for Bury St Edmunds, about the middle of the reign of Queen Anne, and was preserved in the library of that College, together with other calculi, a human skeleton, and a curious assortment of animal and other specimens, indicating that the studies at the College were not limited to books and stars, philosophy and casuistry, but were to be extended, practically, to the various regions of science. Reminders of this, and also of the fact that

¹ An address delivered at the Summer School of Medicine for Qualified Practitioners in Cambridge, June 1895.

² *Philosophical Transactions*, 1723, vol. xlvi.

libraries were the only museums of that time, are still given by a human skeleton in the library at Queen's College, and by one in the library at Jesus College. About thirty years ago the calculus and its companion specimens were transferred to the pathological museum of the university. It is of clinical interest forasmuch as we learn that "the woman had felt much less pain than might have been expected from so large a stone, and might probably have lived much longer with it had she not thought herself well enough to attempt a journey on horseback; for, while she was riding, she was suddenly seized with violent pains that obliged her to be taken off the horse immediately. After this she could never make water unless the stone was first moved, and she continued in great agonies till her death." This corresponds with the fact that the stone is of very compact structure, composed chiefly of concentric layers of uric acid with some oxalate of lime and a thin coating of fusible calculus. It measures 15 in. by $13\frac{1}{2}$ in.¹ It formed, no doubt, very slowly during many years (we cannot tell how many, for estimates as to the rate of growth of calculi are little more than guesses) in the bladder which gradually became accustomed to it and did not resent its presence or object to its weight. Hence, the comparatively little suffering and the long duration of life. In the Norwich collection there is a six-ounce phosphatic calculus which was less meekly tolerated by the female bladder, for it is said to have been ejected spontaneously through the urethra. A still larger stone, weighing forty-four ounces, taken after death from the bladder of Sir Walter Ogilvie, is in the museum of the Royal College of Surgeons of England. He had paraplegia, and the stone is phosphatic. A calculus in St Thomas's Hospital museum weighing twenty-five ounces was, at about the same date as the large one I have shown you, taken after death from Sir Thomas Adams, the philanthropist, draper, Lord Mayor of London, president of St Thomas's Hospital, and the intimate friend of Charles II., to whom he contributed large sums of money, and who created him a baronet, and for his loyalty to whom he was imprisoned in the Tower. He was educated at Cambridge, and founded the Professorship of Arabic in this University in 1632. The calculus resembles the one I have shown you, being composed of compact and regularly laminated uric acid formed around an oval nucleus of more porous uric acid. It appears to have caused little pain or inflammation of the bladder or disturbance of the general health, and, finally, to have proved fatal in consequence of a fall which the worthy baronet had, at the age of eighty-one, in descending from his carriage. It presents a groove dividing it into two unequal parts. This groove, which was probably caused by the projecting hinder edge of the trigone of the bladder, is deep, and with defined edges on what we may suppose to have been the under part of the stone, and becomes shallower and gradually disappears towards the upper part. In a sermon preached "at the solemnity of his [Sir Thomas Adams's] funeral" on March 10th,

¹ See analysis and drawings by Professor Cumming in the first volume of the *Cambridge Philosophical Transactions*.

1667, the groove is described as being, "as it were, a paved way, or rather a channel cut through the stone, for his water to pass," otherwise "the stoppage of it must of necessity have very much added to his smart and lessened his days." The stone is rather uneven and slightly rough on the exterior, being covered, as these large calculi not infrequently are, with a layer of more porous uric acid or urate of ammonia. This coating extends over the groove as well as over the rest of the calculus. A drawing of the calculus, with other particulars respecting it and Sir Thomas Adams, is given in vol. xxi. of the *Transactions of the Pathological Society* by Mr Charles Williams of Norwich, to whom I am indebted for a loan of the sermon.

The largest stone which has, I believe, been removed entire and successfully by the lateral operation is in the Norwich collection. It weighs fifteen ounces, and was extracted by Mr Harmer, a Norfolk surgeon, in the presence and with the aid of Gooch, who gives a representation of it in his work on Surgery. A urinary fistula remained, which Gooch says was kept clean by a little dog licking the part, which gave the patient more ease than any application his surgeon furnished him, and as long as he lived (five years) the dog was his surgeon and kept the wound tolerably clean and easy. The next largest, so far as I know, removed successfully and entire by the lateral operation, is in the museum at St George's Hospital. It weighs eleven ounces, is composed in its middle of uric acid and some oxalate of lime, with a thick coating of compact, concentrically marked phosphate of lime. It was extracted from a man aged forty-three, with much difficulty, by Mr Warrington Haward, in St George's Hospital, who found it necessary to extend the incision into the rectum. A fistula remained, in this case as in the preceding one, but the man was alive and, with that exception, well some years afterwards. In the museum at Guy's Hospital is one weighing thirteen ounces extracted successfully by Mr Mayo of Winchester, but it broke and was removed in fragments. One in the same museum weighing nine ounces was successfully removed by Sir A. Cooper, and another weighing sixteen ounces was also removed entire by the same surgeon, but the patient sank. In the museum of the Royal College of Surgeons of England there is a still larger calculus, the largest, I imagine, which has been removed by the lateral operation. It was dragged through the perineum by Cheselden, and weighed seventeen ounces, but the patient sank the next day. One weighing thirteen ounces failed to be extracted by Mr Dalrymple of Norwich. The largest which I have seen extracted is the uric-acid calculus I show you, weighing eight ounces, which I removed, by means of a strong scoop, through the perineum of a man in the neighbourhood of Newmarket. He recovered without a bad symptom.

On looking over the Norwich collection one is struck with the number of large calculi which have been removed successfully by the lateral operation, and which bear testimony to the reputation as lithotomists which the surgeons of that city have long held. Most

of them are sound, hard, uric-acid stones, and, so far, tell of the sound constitution of the patients, contrasting with these nine calculi from India, sent us by a former pupil, which, though containing uric acid and oxalate nuclei, are, for the most part, composed of phosphates. There is a phosphatic calculus from a negro in the museum of King's College Hospital, and a calculus weighing three ounces and a half, apparently phosphatic, with curious projecting knobs, in the museum of St George's Hospital. It was removed by the lateral operation from a man who had spent the greater part of his life in India. He did not recover. In the museum at St Mary's Hospital there is a phosphatic calculus from India, with two concentrically marked, apparently uric-acid nuclei as large as filberts joined by a band like the Siamese twins. There are, however, in the museum of St George's Hospital two oxalate of lime calculi from India, and in the Royal College of Surgeons of England there is a collection of many calculi, removed by operation from Hindoos and Afghans, which are composed apparently of uric acid; they are compact and present the usual concentric rings. Thus we see that the inhabitants of that region of the world, who are mostly vegetable-eaters, are liable to the same varieties of calculus as our own countrymen. The oxalate of lime is said by Castor to be a more frequent nucleus than uric acid in India, and is attributed by him to the vegetable character of the diet.¹ This fine bristling specimen of oxalate of lime weighing four ounces—a good example of the *calculus spinosus* of Celsus—was successfully removed by myself from a middle-aged man. The largest example of this variety of calculus which I have seen weighed eight ounces. It is in the Royal College of Surgeons of England and was removed from a man in Norfolk aged sixty, who appears to have gone on well for six weeks, but then to have become depressed and sank. These results of the lateral operation pale, however, in interest since the revival, under antiseptic advantages, of the supra-pubic method, by which great stones have recently been removed with success and without much difficulty. In the Royal College of Surgeons of England there is a calculus weighing thirty-four ounces and a half, six inches long, and four inches in diameter, which was removed at Cairo by Mr Milton, by the supra-pubic operation, from an Egyptian fellah, aged sixty, who was at the time in bad health. The operation is described as one of "laparotomy," for the peritoneum, as well as the bladder, was opened above the pubes. The man lived two months and a half and then died from kidney disease.² In Ashhurst's *International Cyclopædia of Surgery*, vol. vi. p. 162, a case is quoted in which a stone, weighing forty ounces and a half, and measuring seventeen inches in circumference, was removed from a man aged thirty-nine, by the supra-pubic method, by a Brussels surgeon, the patient dying eight days afterwards. This is probably the largest stone ever removed from the living human bladder. It is somewhat strange, and not particularly creditable to

¹ Ashhurst: *International Encyclopædia of Surgery* vi. 160.

² *The Lancet*, Sept. 16, 1893.

me, that, having tested this method in 1848 on a lad aged fourteen who had shown symptoms from birth,¹ I should not again have resorted to it till within the last few years, when it had been revived by others, especially as the case taught me that I over-estimated the ill-effects that were likely to result from extravasation of urine into the loose tissue about the bladder. I carefully emptied that viscus before the operation, instead of washing it out, and perhaps filling it with antiseptic fluid, as is now done. Yet, in spite of my precautions, when I cut into the bladder, to my dismay a considerable quantity of urine (pent up, I suppose, in the ureters, as may be seen to have occurred in a specimen in the Middlesex Hospital, where, with a calculus in the bladder, the ureters, pelves, and calices of the kidneys are enormously dilated) flowed out and soaked into the surrounding tissues; yet no ill resulted. The thickened bladder had misled me somewhat as to the size of the stone which, as you see, is not very large, and weighed only 750 grains. The lad made a good recovery; and some time afterwards I extracted, by the lateral method, a stone which had formed upon and was adherent to the cicatrix of the former operation.

The nucleus.—The nucleus, which is the incipient or foundation, and usually the central part, is obviously the most important part of a calculus, that to which attention has been most especially directed. It commonly forms in the kidney and consists of uric acid, oxalate of lime, or cystine—of the first most frequently, of the last rarely. Its formation depends upon one or both of two causes: first, an unusual quantity of one of the more easily precipitable constituents of the urine (uric acid or oxalate of lime), when a very slight cause will lead to the precipitation and union of the crystals, which may take place in the uriniferous tubes or in the calices of the kidney; secondly, a slight increase, or alteration in the quality of the mucus in the secreting tubes or calices of the kidney may exert what is known as a colloidal influence upon the forming crystals, modifying their shape or reducing the crystallisable material to a more or less amorphous and cohesive condition, in consequence of which they adhere together into masses or calculi. This alteration in the mucus may possibly, in some cases at least, be caused by the abnormal presence of crystals in the kidney, the two conditions thus acting and reacting on each other and combining in the production of calculus. That the mucous condition is a very important feature in the process is shown by the well-known experiments of Mr Rainey, followed by the observations of Dr Ord;² and it is maintained that without this colloidal influence the crystals have very little tendency to adhere together. Streaks of the granular or amorphous uric acid and of dumb-bells of calcium oxalate formed under this influence are not uncommonly found in the uriniferous tubes, especially in infants and young children, constituting the “uric acid infarction” of Virchow. Many years ago a medical man about sixty, of gouty diathesis and sensitive temperament, who

¹ See *Provincial Medical and Surgical Transactions*, vol. xvii.

² *The Influence of Colloids upon Crystalline Form and Cohesion*, 1879.

was liable to attacks of pain in a kidney, told me that after each attack he was conscious of something passing along the ureter into the bladder, and, being apprehensive of the formation of calculus, he used to watch on each occasion for the passage with the urine of what he called a "bleb of mucus." His apprehensions were realised, for after one of these attacks the looked-for "bleb" did not appear, a stone formed, and I subsequently lithotomised him. He recovered from this, but died subsequently from some kidney disease. When two or more calculi find their way into the bladder they usually, I believe, come from the same kidney; and in the *Transactions of the Pathological Society*¹ two instances are recorded by Dr Harley, in each of which numerous small calculi were found in one kidney (in one case in the left kidney, where they were of triple phosphate, and in the other instance in the right kidney, where they were of uric acid), the opposite kidney being quite free. Here the formation of the calculi evidently depended upon some peculiarity, probably in the mucous secretion, of the kidney. The importance of this view of the pathology of calculus, with regard to the investigation of the causes of the disease in particular districts, and to the measures to be taken for its prevention, must be borne in mind. It gives some support to the

FIG. 1.—Four nuclei in one calculus. (Cambridge collection.)

principle involved in Dr Yellowby's idea that the Norfolk dumplings and the indigestion resulting from them were a cause, if not *the* cause, of the prevalence of calculus in that county. The porous character of the nucleus, as compared with the layers formed upon it, which may often be observed, accords with its mucous origin. Two or more nuclei are not very infrequently found in a calculus. These are usually of uric acid or urate of ammonia. In this specimen (fig. 1) there are four nuclei; and in one in University College five uric-acid nuclei are embedded in a mass of phosphates, forming one large stone. In some instances they are small, and in some flattened by apposition. The junction of such may have taken place in the kidney, though I am not aware that renal calculi have been found with multiple nuclei. Now and then one sees two nuclei united by a band (as just mentioned) like Siamese twins and enclosed in a common envelope—indeed, a large number of small calculi may be united by phosphates into a single stone, as in a specimen examined by Dr Beale.² Occasionally, larger stones are thus joined together,

¹ *Transactions of the Pathological Society*, vol. xv. p. 147.

² *Urinary Deposits*, 1869, p. 419.

the uniting medium being commonly phosphatic, and two or more calculi, lying in apposition in the bladder, may become covered over and cemented by phosphatic material. In one specimen two good-sized, cone-shaped calculi, with their bases apposed but not in contact, are enveloped in a mass of porous, apparently phosphatic, material. In a specimen in King's College Hospital a small porous uric-acid stone is appended to, and united by phosphates with, a large, compact uric-acid stone which has an oxalate nucleus. The most remarkable example of such union is presented by the large seventeen-ounce calculus removed by Cheselden and represented in fig. 2, taken from

FIG. 2.—Three large uric-acid calculi united by phosphates.
(Catalogue of the Royal College of Surgeons.)

the catalogue of the Royal College of Surgeons of England (Plate III., fig. 1). In it three large uric-acid calculi, but little adapted to one another and not very closely approximated, are united by earthy phosphates. The central part of each of the three consists of porous uric acid or urate of ammonia, and the surrounding concentrically marked and more compact uric acid looks as if the calculi had lain in apposition, and that some shifting of them upon one another had taken place before they became united by the phosphatic deposit. The multiple nuclei are, as I have said, commonly composed of uric acid or urates. The oxalate calculi are usually single, and rarely have more than one nucleus; and, indeed, this material is seldom passed in the form of gravel. There is, however, in the museum in

Guy's Hospital a specimen in which four nodulated nuclei of oxalate of lime, as large as beans, are united by urates and surrounded by layers of uric acid, forming a large stone; and in the museum of the London Hospital there is a large calculus composed of two calcium oxalate calculi of unequal size enclosed in a mass of phosphates. When nuclei remain separate they form multiple calculi which, by apposition and mutual friction, commonly become faceted, and often in a manner rather difficult to account for. This, however, is not always the case. In the museum in Guy's Hospital there are sixteen calculi taken from a bladder after death; they are nearly as large as walnuts and are spherical and smooth on the surface. Here, also, are sixteen spherical, smooth calculi of rather smaller size. In the Norwich collection there is a large cuboidal calculus with four facets, upon each of which is applied a flattened calculus faceted on one side, the whole forming a nearly spherical mass which resisted the attempts to remove it by the lateral operation. The portions came away separately subsequently, through the wound, into the bed, but the patient did not recover.

When the nucleus or the calculus has reached the bladder it does not comport itself quite like an ordinary foreign body. The latter, as we know, whether it be a piece of bougie, a hairpin (as in this specimen), a mass of soap (as in two specimens in the Royal College of Surgeons of England), or any other substance, becomes encrusted with phosphates consequent on the irritation caused by it in the bladder, the only exception to this that I have known being the specimen in the Royal College of Surgeons of England in which a needle is the nucleus of a uric-acid stone; whereas a calculus usually increases by the addition of material like that of which it is composed. The reason of this difference must be that the calculus causes less irritation than a foreign body, which perhaps we should scarcely have expected. That a hairpin should be a source of considerable worry may easily be believed, but we should not have thought that a piece of bougie would have proved a greater irritant than a spinous oxalate calculus. True, the calculi may, and often do, become coated with phosphates. Usually, however, the addition to a calculus of uric acid, oxalate of lime, or cystine does not consist of phosphates, but of uric acid, oxalate of lime, or cystine, as the case may be. It is somewhat remarkable that this should be so, and should sometimes go on steadily for many years, as in the instance of the woman whose large stone I have shown you, in that of Sir Thomas Adams and in others, especially when we remember that oxalate of lime or oxalic acid and cystine are not commonly present in the urine at all, or indeed in the blood,¹ and that uric acid is present in small quantities, about six to ten grains only being passed in the four and twenty hours, and it does not exist in a free state in the urine, but is held in solution by an alkaline base from which it must be liberated before it can settle on a calculus.

Increase of calculi in size.—The addition to a calculus is probably

¹ Dr Beale found cystine continuously present for a long time in the urine of a young man who was otherwise healthy.—*Urinary Deposits*, 1869, p. 884.

effected by the same means as that by which the nucleus is formed—that is to say, by the influence of the mucus in the urine. This, where in contact with the stone and resting in the interstices of its surface, attracts, sets free, and modifies the uric acid, increasing its cohesive quality and causing it to settle upon the stone, and the quality of the uric acid thus added will depend upon the amount and quality of the mucus. When the latter is in small quantity the acid crystals will be little altered and will be slowly deposited, constituting the compact material of which the greater number of large, slowly forming calculi are composed. When the mucus is more abundant the uric acid is deposited in greater quantity, more quickly, and in more granular amorphous form and more irregularly, constituting the porous variety of which many stones are entirely, or in varying degrees, composed. The porous and the compact materials often vary in different periods of the formation of the same calculus, not infrequently succeeding one another and telling of successive periods of greater or less irritation of the bladder. The same remarks apply probably to the oxalate and cystine calculi, though variations in density in different parts of these are not so common as in those composed of uric acid.

Form of calculus.—Each variety of calculus takes its own form, the uric acid being oval and flattened (which is also commonly the case with the cystine), and the calcium oxalate being spherical. This cannot depend upon the surroundings, for the form differs in the two cases, and each assumes its particular form from the first—that is, when the stone is small. In the calcium oxalate the form may be given by the crystals radiating from the centre in needle-like lines and shooting out into the spines or tubercles on the surface; and in the uric-acid calculus it must likewise be some disposing property in its particles which gives the flattened oval shape, and which also causes the tubercles often seen on the surface and the lamination in its structure. Though the predominant form of the uric acid calculi is a flattened oval, especially when the substance is compact, it is liable to great varieties.¹ Often it is prolonged in certain directions by the deposit upon it of the porous uric acid or urate of ammonia, or of the two combined, the particles of which, being more or less deprived of their crystallising quality, lose proportionately their form-determining property. It not uncommonly happens that the calculi are prolonged at one or both ends of the oval; and in Sir Henry Thompson's cabinet in the Royal College of Surgeons of England there is the curious instance of a square-shaped calculus in which the four angles have been prolonged by porous uric deposit upon each, the whole being covered over by more compact uric acid, as though, for a given and short period, the irritation of the bladder by the four corners had determined the presence of mucus upon them, with the consequent porous condition of the uric acid. Occasionally, as in the specimen represented in fig. 3 from the catalogue of the

¹ They may be nearly spherical in shape, as is the 8 oz. calculus mentioned above; and Mr Vincent Jackson, of Wolverhampton, tells me he has a spherical uric-acid calculus in his possession.

Royal College of Surgeons of England, a uric-acid calculus is capped at one end with a thick layer of compact striated uric acid. The smooth groove on the surface between the two parts in this stone has suggested that the one part may have been formed in a cyst and the other part in the bladder, but, in addition to the fact that encysted calculi are usually phosphatic, there is a specimen in the College in which there is a similar cap at each end. A calculus in the museum at St Mary's Hospital has a small cap of the like material at one end,

—3

FIG. 3.—Uric-acid calculus capped at one end by compact uric acid.
(Catalogue of the Royal College of Surgeons.)

and the whole is covered with a layer of phosphate. A specimen in Sir Henry Thompson's cabinet looks as if a number of small uric-acid calculi had settled upon and adhered to an elongated stone of the same material, this being, I suppose, in reality, an exaggeration of the granular or tuberculated condition not uncommon in uric-acid calculi. The nucleus may be at one end, the calculus having been

prolonged in the opposite direction into a finger-like form by compact or porous uric deposit, as in this specimen. Here is a triangular flattened calculus; and in a specimen in the museum at St George's Hospital a calculus has acquired an hour-glass shape from increase at both ends, the nucleus being in the middle. This, I should say, is thought to have been due to the solution of the middle part by the urine, which can scarcely have been the case, for the calculus presents the same smoothness and character of contour over its whole surface. Such constrictions or grooves dividing a calculus into two or more equal or unequal parts are occasionally seen (fig. 4), and they are commonly attributable to projections into the bladder of the hinder edge of the trigone or some other bands which have impressed the calculus. They are generally smooth, as smooth as, or smoother than, other parts of the surface of the calculi. Occasionally, but more rarely, the constriction has been caused by the formation of one part of the stone in a cyst and of the other part in the bladder

3

FIG. 4.—Calculus with phosphatic deposit at both ends and deep groove in the middle. (Cambridge collection.)

and represents the narrow orifice of communication between the bladder and the cyst. In such cases, as I have said, the calculi are, so far as I have seen, phosphatic.¹ Various forms are given by the addition of lime salts, and it is to be remarked that these are often deposited upon the ends of the oval uric-acid calculi, extending their long axes and leaving the rest of their surfaces

¹ There has been lately added to the museum at Cambridge the bladder, with cystitis and thickened wall, from a lad who died in Addenbrooke's Hospital. The ureters were dilated, and there was hydronephrosis on both sides. On the left side of the bladder, near the entrance of the ureter, but separate from it, are two small orifices of sacculi, each of which was filled by a phosphatic calculus nearly the size of a walnut, of hard structure and with concentric laminae. These two sacculi displaced and stretched the ureter, and must, in some degree, have obstructed the passage of urine through it. On the right side, also near the ureter, but not interfering with it, is a small sacculus which did not contain a calculus. There was no calculus in the bladder, and it is not easy to decide what determined the formation of the sacculi and the formation of the calculi in the two sacculi on the left side. Still more recently a specimen has been added of enlarged prostate, with numerous small calculi lodged in sacculi, or, rather, fasciculated depressions in the bladder.

uncovered, of which fig. 4 is an illustration. Does this indicate that the salts have a tendency to settle upon the ends or more prominent parts of the calculi, as in the instance of the square uric-acid calculus before mentioned, in which a collection of porous uric acid is seen in each of the four corners? This large calculus, the other half of which is in St Bartholomew's Hospital, is partially covered by thick, defined, irregular bands of phosphates, the intervening parts of the surface being free. The cause of this irregularity in the deposit I cannot tell. The calcium oxalate calculus is less liable to varieties of form than the uric acid, perhaps because the needle-like radiation of its crystals is a more determined factor, and leads to the more definitely spherical shape. In Guy's Hospital, however, there is a square calculus of this material, also a cast (I believe) of one which is elongated, one of large size marked by a deep groove, and others of different shapes. In the museum of St Thomas's Hospital there is an example of several faceted calcium oxalate calculi quite smooth on the surface and nearly colourless, both these peculiarities being very rare, for this variety of calculus is usually single and dark-coloured. In that museum also is an instance in which knobs of oxalate have formed upon a uric-acid calculus.

Concentric and radial fissuring and fragmentation of calculi.—There is in the uric-acid calculi, evinced more particularly when they have become dry, a tendency to crack into layers and also to split radially, such as may be seen in the transverse section of the branch of a tree. This probably depends upon the concentric and radially fibrillar arrangement of the particles of the calculus, resembling that which was noticed by Mr Rainey in the small calcium carbonate spheres resulting from the action of gum upon ammonium carbonate. It facilitates probably the breaking up of the stone under the lithotrite, and may possibly, under certain conditions, such as some change in the cementing material of the calculus, lead to the spontaneous division of the stone into fragments in the bladder. A supposed example of this is represented in Plate XII., fig. 10, of the catalogue of the Royal College of Surgeons of England, taken from a specimen in the museum at St Bartholomew's Hospital, in which a portion of the outer layer of the calculus has become detached. One cannot but suspect that such a fragment may have been broken off in sounding. There do not appear to be any other fissures in the calculus, and it is difficult to see how it can have been spontaneously detached in the bladder. The same remarks apply to the two cases mentioned by Mr Southam;¹ and in the third case, communicated to him by Mr Luke, the lithotrite had been used and the stone had twice slipped from under it. Instances of supposed spontaneous disintegration of calculi are also given by Dr Ord.² Mr Coulson³ mentions a case in which fragments of the shell of a medium-sized uric-acid calculus were spontaneously detached and passed from the bladder. The

¹ *Brit. Med. Jour.*, Jan. 4th, 1868.

² *Op. cit.*, p. 93.

³ *Transactions of the Pathological Society*, vol. xv. p. 143.

detachment was judged to have been caused by the violent contact of two stones during severe attacks of bladder irritation.¹

Colour and concentric colour-markings.—Each variety of calculus acquires its particular colour. The uric acid attracts the urochrome of the urine, which gives it, whether in the form of gravel or stone, a reddish-brown or fawn colour. Owen Rees is said to have seen one perfectly white.² The dark colour of the calcium oxalate has been attributed to an admixture of the colouring matter of the blood; but its uniform diffusion seems rather to point to its depending upon some modification of the colouring matter of the urine which takes place during the formation of its crystals. I have already mentioned an instance in which the colour was absent. The oxalate so rarely passes as gravel that we have not much opportunity of determining its colour under those circumstances. The disposition of the colour in alternating deeper and fainter lines shading into one another, and giving the concentric markings common in compact uric-acid calculi, is not quite easy to account for. The lines are usually in complete circles, though varying in depth and definiteness in different parts of the circumference, and in different parts of the thickness of a calculus. Yet in this thirty-two-ounce stone they have evidently been formed in fairly regular order through many years. Such colour-markings are by no means peculiar to uric-acid calculi. They are sometimes seen faintly in the oxalates and in the harder phosphates, though in the latter they may have relation to admixture with uric acid or calcium oxalate in certain of their layers. They may be discernible in gall-stones, and are often strongly marked, as in this specimen, in the stones composed mainly of carbonate of lime, found in the intestines of horses, and also in other instances. Are we to suppose, in the case of uric-acid calculi, that they depend upon alternating changes in the urine which indicate subtle changes in the system not otherwise evinced, such as might be caused by changes of food, changes of temperature as in the rings in trees, or other influences? They are not numerous enough to be diurnal, and they are too numerous to be annual. Or do they depend, like the concentric rings in bone, which exhibit, and are caused by, the arrangement of the bone corpuscles, upon some determining quality in the material itself? The frequently-occurring calculi in which layers of compact and porous uric acid exist in super-imposed layers, with varying amounts of urate of ammonia, also the “alternating calculi” composed of uric acid, calcium oxalate, and phosphate of lime occurring and recurring in varying layers, must depend upon corresponding changes in the urine, and form an argument in favour of the former hypothesis. At any rate, a question of some interest in pathology and physiology is opened up by these markings and other alternations observable in calculi.

I have mentioned that the more porous uric-acid substance differs from the compact in the greater contingent of mucus, which gives to

¹ See also “Case of Spontaneous Fracture of Uric Acid Calculi,” by Dr Plowright, and discussion at a meeting of the *Pathological Society of London*, in *The Lancet* of Oct. 19th, 1895.

² Ashhurst, *loc. cit.*, vol. vi. p. 165.

it a more or less granular or amorphous character, and that it does not acquire the regular colour-markings just described. It does, however, often present a radially coarse fibrous structure with traces of concentric layers. In this specimen (figs. 5 and 6) the radiating bars are crossed and connected by tiers of concentric strata; and the two have the effect of dividing up the calculus in such a manner as to

A

FIG. 5.—Porous uric-acid calculus, showing radial and concentric disposition of fibres. (Cambridge collection.)

FIG. 6.—Section of above, magnified, showing more or less rectangular chambers enclosed by the radial and concentric fibres.

enclose regular squares or elongated spaces or small chambers with defined walls and angles. How the curious arrangement came about I cannot tell. The porous calculi usually conform to the flattened oval uric-acid type, and when the porous is added to the compact uric acid it commonly does the same; but, as I have before said, it may be limited to some part or parts of the surface, perhaps to the more projecting parts, as the ends, and give in that case an elongated form to the calculus.

Erosion of calculi in the bladder.—I have not been able to satisfy myself of any clear evidence of the solution or erosion of calculi in the bladder. The grooves on the surface often attributed to that cause are usually smooth and crescentic, or circular, and are obviously due to the projection of rugæ or bands from the internal surface of the bladder, which have interfered with the deposit upon the stone where they embraced it. The calculus is not uncommonly thus modified, acquiring an hour-glass shape, or being constricted in various ways. The hinder edge of the trigone, as seen in Sir Thomas Adams's stone, may be the cause, or the pressure of the urethral orifice upon a calculus which projects into the more yielding prostatic part of the urethra. These supposed evidences of erosion are most common in compact uric-acid calculi, which one would not judge most likely to undergo solution. The coloured rings may now and then be seen to be incurved at the grooves, but they more commonly stop short and terminate in rounded ends at the margins of the grooves (as seen in fig. 4); or they may terminate even more abruptly so as to give some countenance to the erosion theory, not, however, enough to counterbalance the facts that the grooves are smooth; and in some instances, even where the rings terminate, as I have mentioned, the grooves are known to have been caused by constricting bands, and the remainder of the surface of the calculus gives no indications of a solvent action. Further, in some a coating of deposit, uric or phosphatic, has formed over the whole surface, including the grooves, which scarcely accords with the view of erosion of any part. The rough, sharply-defined depressions or holes seen upon some calculi are more suggestive of erosion, but they probably depend upon irregularity in the phosphatic or other deposit rather than upon erosion. There is in the museum at St Thomas's Hospital a large uric-acid calculus resembling that from Sir Thomas Adams, and with a similar constriction or groove. The exterior is described as being "water-worn and the colour washed out." It presents to me more the appearance of being coated with a layer of rather lighter material than the rest of the stone, intermixed probably with some phosphates, which had been deposited in an irregular or tuberculated manner, so as to give the impression that the surface had been acted on by the urine or "water-worn." One is rather at a loss to know by what ingredients in the urine the solution, whether of uric or phosphatic calculi, could be effected. It is possible that certain changes in the urine, acting upon the cementing material of the surface of the calculus, as suggested by Dr Ord¹ with reference to the disruption of calculi, might lead to the removal of particles which pass away with the urine; but the whole subject is, I think, still *sub judice*.

Phosphatic calculi.—Phosphatic calculi do not assume any regular or special form, like the uric or oxalate calculi. When added on to other calculi, the phosphatic concretion commonly continues the form of that upon which it is laid, or, as I have already said, it may prolong it in certain directions or be deposited in various ways:

¹ *Op. cit.*, p. 97.

and it is said not to possess the property of cohering into a calculus or upon a calculus, except in the presence and under the colloidal influence of mucus or pus. In the museum at St Mary's Hospital there is a uric-acid calculus with phosphatic deposit on one side only, as though the stone has rested quietly on one surface in the bladder and the phosphates had been limited to the uncovered or exposed part. In that museum is also a curious pyriform phosphatic calculus composed apparently of eight faceted pieces accurately adapted to one another; and a finger-like process which extended into the urethra is marked off from the remainder by a deep constricting groove formed by the neck of the bladder. It was taken after death from a man who had for many years suffered from the effects of fracture of the spine. In the same museum there are also two disc-shaped faceted phosphatic calculi of the size of beans, removed from the phimosed prepuce of an old man who died from hydronephrosis. They are said to have caused retention of urine. It is often stated that phosphatic deposit, being due to inflammation of the bladder and consequent decomposition of the urine, is a final deposit upon a calculus and is not followed by any other material. This, however, is disproved by numerous specimens in which rings of uric acid and calcium oxalate are seen encircling the phosphatic formation or alternating with it. In some examples the alternating and waving disposition of the oxalate presents a variegated and pretty section, not unsuitable, as was remarked to me, for a lady's brooch. In an example at the Royal College of Surgeons of England a phosphatic calculus with a considerable projection at one part is encircled by a waving line of calcium oxalate. In these cases the phosphate is usually compact, indicating that the bladder inflammation upon which it depended was not very severe. I do not think that the looser, softer phosphatic substance, the result of more active inflammation, is followed by other deposit—at least, I have not met with an instance in which it was so.

Bone, teeth, and hair in the bladder.—These portions of bone with teeth and hair, covered with phosphate of lime, I removed through the urethra from the bladder of a woman who quite recovered from the operation. The finger introduced into the bladder did not discover any other disease. The supposition is that the masses originated in the ovary, probably in a congenital cyst, and found their way into the bladder, after the manner in which an extra-uterine foetus—or the bones of one—occasionally travels into the rectum. In University College there is a phosphatic calculus elongated at one end where there is a foetal tibia which formed the nucleus of the stone. After the death of the patient other remains of a foetus were found in the right iliac fossa. Dr Beale¹ mentions an instance in which hairs that have escaped from an ovarian cyst into the bladder formed the nuclei of calculi; and gall-stones are said to have been passed from the urinary bladder, having found their way into that viscus in consequence of a communication found between it and the gall-bladder.²

¹ *Urinary Deposits*, 1869, p. 419.

² Ashhurst, *loc. cit.*, vol. vi. p. 164.

Notices of New Books.

RECENT MEMOIRS ON THE ANATOMY OF PRIMATES.

- I. *Contributions to the Anatomy of Anthropoid Apes.* By F. E. BEDDARD. *Trans. Zool. Soc.*, xiii., 1893.
- II. *A Description of the Cerebral Convolutions of the Chimpanzee known as "Sally," with Notes on the Convolutions of other Chimpanzees and of two Orangs.* By W. B. BENHAM. *Quart. Journ. Mic. Sci.*, Nov. 1894, and *Linacre Reports*, vol. ii., Oxford, 1895.
- III. *Untersuchungen über die Grosshirnfurchen der Primaten.* Von W. KÜKENTHAL and TH. ZIEHEN. *Jenaische Zeitsch.*, vol. xxix., 1894.
- IV. *Notes on the Dissection and Brain of the Chimpanzee "Gumbo."* By THOS. DWIGHT. *Memoirs of Boston Society of Nat. History*, vol. v., No. 2, 1895.
- V. *Observations sur deux Orang Outans adultes morts à Paris*, par MM. A. MILNE EDWARDS, J. DENIKER, R. BOULART, E. DE POUSSARGUES, F. DELISLE. *Nouvelles Archives du Museum d'histoire Naturelle*, 3^e série, T. vii., Paris, 1895.
- VI. *The Papillary Ridges on the Hands and Feet of Monkeys and Men.* By DAVID HEPBURN. *Scientific Transactions of the Royal Dublin Society*, vol. v., series 2, 1895.
- VII. *Sur les plis cérébraux des Lémuriens en général et du Loris grêle en particulier*, par THÉOPHILE CHUDZINSKI. *Bulletins de la Société d'Anthropologie*, July 4, 1895.
In this memoir, in addition to the brain of Loris, the author describes and figures those of *Lemur nigrifrons* (Maki) and *Lemur indri*.
- VIII. "On the Ligaments of the Catarrhine Monkeys, with reference to corresponding Structures in Man"; "On a theory to account for the various arrangements of the flexor profundus digitorum in the hand and foot of Primates"; "The Growth of the Brain in Men and Monkeys, with a short criticism on the usual method of stating Brain Ratios"; "The Modes of Origin of the Carotid and Subclavian Arteries from the Arch of the Aorta in some of the higher Primates"; "On a variation that occurs in the Manubrium Sterni of higher Primates"; by ARTHUR KEITH, M.B., have appeared in the *Journal of Anatomy and Physiology*, vols. xxviii., xxix., xxx.

I. In this memoir Mr F. E. Beddard describes the anatomy of two anthropoids in the collection of the Zoological Society of London.

The Chimpanzee "Sally" had been in the Garden for eight years and some months. He regards it as a specimen of the Bald-headed Chimpanzee, *T. calvus*. He describes its external characters, including the ear, hand, and foot; the muscular system, palate, and brain. The brain, after removal of the pia mater and immersion for four months in spirit, weighed 8½ oz. He also examined the Orang known in the Gardens as "George," and gives an account of its external characters, muscular system and palate, but he does not describe or figure the brain.

II. Dr Benham has entered into a more detailed examination of the brain of the Chimpanzee "Sally" than was done by Mr Beddard, and has adopted the nomenclature employed by Professor D. J. Cunningham in his well known memoir on the surface anatomy of the Cerebral Hemispheres, 1892. In this brain there was an absence of a well defined operculum in the parieto-occipital region, and a diminution in extent of the so-called "affenspalte" or Simian fissure, so that the brain is in this region more like the brain of the orang and man than of the more ordinary chimpanzee, but nearer to man than the orang. Benham regards "Sally" as merely a variety of *T. niger* rather than the species *T. calvus*. From a comparison of the brains of several chimpanzees, Benham concludes that the occipital operculum presents great variations in size, and is often unsymmetrical in the two hemispheres. The affenspalte seems to be homologous with the sulcus transversus occipitalis of Ecker, and to be independent of the bifurcation of the intraparietal fissure. The parieto-occipital fissure on the cranial surface of the hemisphere is independent of the affenspalte, and is not synonymous with the fissure frequently named in the text-books "external parieto-occipital." In some chimpanzees the anterior limb of the Sylvian fissure has a ramus ascendens and a ramus horizontalis which enclose a pars triangularis or frontal operculum, overlapping the insula. The paper concludes with some notes on the brains of two orangs.

III. Messrs Kükenthal and Ziehen have conducted an investigation into the furrows and convolutions of the hemispheres of a number of apes. They have described and figured examples of the genera *Midas*, *Hapale*, *Brachyurus*, *Pithecia*, *Nyctipithecus*, *Callithrix*, *Chrysotrix* (no figure), *Cebus*, *Ateles*, *Lagothrix*, *Mycetes*, *Cynocephalus*, *Macacus*, *Cercopithecus*, *Cercocebus*, *Semnopithecus*, *Hylobates*, *Orang* and *Chimpanzee*; the descriptions are methodically written, and the figures are arranged so as to admit of the ready comparison of one brain with another. They also draw attention to the human brain in comparison with those of apes, and formulate their conclusions in several propositions which are too long to incorporate in the space at our disposal.

IV. Professor Dwight gives an account of the dissection of a male Chimpanzee "Gumbo," probably 10 to 12 years old. He had not quite reached his full size, as some of the epiphyses were distinct and

the permanent dentition was not complete. In his account of the muscular system he has made especial use of Dr Hepburn's account of the limb muscles of the anthropoids published in this *Journal*, vol. xxvi. In his account of the brain he recognises a pars triangularis in the inferior frontal convolution, already referred to in Benham's description. The arcus parieto-occipitalis, or pli de passage of Gratiolet, surrounds the external parieto-occipital fissure; it is quite uncovered by the operculum. The "affenspalte," symmetrical on the two sides, runs from the median line, just behind the arcus, to the outer lower border of the hemisphere. The lateral, superior and mesial surfaces of the hemisphere are figured.

V. M. Alphonse Milne Edwards writes a short introduction to the description of the dissection by the naturalists attached to the Museum of the two male Orangs, well known to visitors to the Jardin d'acclimation in Paris. The largest of these, "Maurice," was 1 m. 40 in height and weighed 3 kil. 500; the smaller, "Max," was 1 m. 28 in height and weighed 65 kil. 500. Milne Edwards considers that there is only one species of orang, but that individuals can differ materially in height, dentition, and osteological characters. The dissection of the laryngeal sacs, the fatty excrescences, the lungs, and the brain was entrusted to MM. Deniker and Boulart. They have given a lucid description of the larynx and its sacs and the muscular apparatus associated therewith, the arrangement of parts being illustrated by several figures. The brain of the largest orang was the only one examined. The entire encephalon, when removed from the skull, weighed 0 kil. 400. After 10 days in alcohol and the removal of the pia mater the weight was only 264 grammes; 44 days later the weight was 260 grammes,—the cerebellum, bulb, and pons being 37 grammes, the hemispheres 223 grammes. As the weight of the body was 73 kil., the brain was about 6 per cent. of the body. The hemispheres completely covered the cerebellum, but their posterior border was in the same vertical plane as that of the cerebellum. M. de Pousargues described the male genital apparatus, and shows wherein it agrees with and differs from that in man; the characters are illustrated in a large quarto plate. Notes on the osteometry and craniometry are contributed by M. Delisle, who also gives a description, with figures, of the physiognomy of the animals. In its cranial capacity, Maurice measured 385 c.c.; Max 470 c.c. Nine other crania of the orang were also cubed and found to vary from 475 to 340 c.c.; the mean capacity of the eleven skulls was 408 c.c. The actual and relative length of the bones of the limbs are given, and a number of measurements of the crania.

VI. Dr Hepburn's research into the papillary ridges on the hands and feet of monkeys, illustrated with five quarto plates, is one of interest and novelty. It was conducted on monkeys in the collection of the Royal Zoological Society of Ireland. Although the author experienced difficulties in conducting the inquiry owing to the rest-

lessness of the animals, yet by patience and care a number of good impressions were procured of the palms of hands and soles of the feet of *Ateles ater*, *Cynocephalus babouin* and *mormon*, *Cercopithecus niger*, *Cercocebus fuliginosus*, *Macacus cynomolgus*, and in addition dab impressions of the right index and medius of the chimpanzee were obtained. The patterns of the ridges in the lower monkeys were much more simple than in man; they were modified loops, whose cores were multiple longitudinal rods. In the chimpanzee and orang the patterns more closely approximate to man; they are more restricted in size and complex in outline, owing to the more circumscribed nature of the area which they cover. The papillary ridges and furrows are adjuncts to the prehensile function and power of the hands and feet, as well as arrangements associated with increased sensibility and discrimination of touch.

Annual of the Universal Medical Sciences. Edited by C. E. SAJOURS and Seventy Associates. Five volumes. F. A. Davis & Company, Publishers, Philadelphia, New York, Chicago. 1895.

THIS Annual continues its useful career, and gives a comprehensive retrospect of the progress of medical science during the preceding year. A section in vol. v. is devoted to a synopsis of some of the more recent literature of Anatomy and Anatomical Abnormalities. This chapter is prepared by Drs Testut and Vialleton, who deserve great credit for the manner in which they have done their work, embracing as it does a review of the writings of men of various nationalities.

It is conveniently divided, for the purpose of reference, into the following parts: general considerations, bones, articulations, muscles, heart and circulation, nerves, digestive apparatus and genito-urinary apparatus, so that at a glance one may select the particular subject in which one may be interested. The whole concludes with a section on malformations. After the name of each author is printed a number and date, the former referring to the journal from which the extract has been taken, the corresponding number being placed against the journal quoted in the reference list at the end of the volume.

More space is given to the literature of the nervous system, and the abstracts are more detailed, a result that was to be expected from the number of persons who are devoting their attention to the study of this subject. In the part dealing with malformations, many interesting and curious anomalies are recounted, the greater number of them occurring in the hands and feet, the hereditary nature of these varieties being pointed out. We notice, too, the report of another case, in which the heart and stomach were placed upon the right side and the liver on the left, while in another the viscera were found on auscultation to be inverted. The five volumes reflect great credit upon editor and publisher alike, and no trouble appears to have been spared to make it as complete as possible, and of value for reference.

The Structure of Man an Index to his Past History. By Dr R. WIEDERSHEIM, Professor in the University of Freiburg in Baden, translated by H. and M. BERNARD, the Translation edited and annotated, and a Preface written, by G. B. HOWES, F.L.S., Professor of Zoology, Royal College of Science, London. Macmillan and Co., London and New York, 1895, 8vo.

THIS book, as the editor says, "is an endeavour to set forth the more salient features in the anatomy of Man which link him with lower forms, and others in that of the lower forms which shed a special light on parts of the human organism," and as such it is an interesting, instructive, and suggestive work, though many will feel that in all the details it is not quite convincing. The main features of similarity between man and other animals are obvious enough, showing him, in his minute structure as well as in his gross anatomy, in his physiology as well as in his development, to be a member of the animal group. The difficulty, and, of course, the proportionate interest, arise when we come to draw inferences from these similarities as to his primitive history and origin. In this work, development, so-called embryonic remains and varieties, are the chief keys which are used to unlock the puzzles; and they are freely and ably used. Inferences, however, in this, as in other branches of science, often outrun facts. There would, indeed, be no speculation if it were not so; and facts are often made to conform to, and so unduly bent to support inferences; facts and inferences thus acting and reacting upon one another. This, doubtless, has been rather markedly the case with regard to the subject of Evolution since the Darwinian theory respecting it has been so prominent before men's minds, and has exerted such a fascination over them.

The first examples are drawn from the tegumental system. The lanugo or foetal hair which appears about the twelfth week and breaks through at the end of the fifth month, and which covers the whole body or nearly so, "renders it probable that man was, in his primitive state, far more hairy than at present," and this view is felt to derive confirmation from the variable amount of it which is found in individuals of many nations, and the extensive covering of it possessed by the Ainos. The claw-like character of the nails on the lesser fingers and toes are also referred to. Many examples of supernumerary mammæ and teats, which occur both in man and woman, are given and quoted. The variations in the number of the coccygeal vertebræ, the fact that "at an early stage of development the human embryo possesses, at the posterior end of the body, in direct continuity with the developing axial skeleton, a free projecting pointed appendage, bearing an undeniable resemblance to the tail of a lower animal," though it is not clear that the latter persists into extra uterine life as a tail, also the variations in the shifting of the pelvis forwards, are adduced as occasional persistences of embryonic conditions similar to those of the lower animals. The occasional deficiency in the first thoracic rib suggests that the process of degeneration at the upper end of the thorax may be in progress, though it here goes on at a

slower rate than that at the lower end, because the attachment of certain muscles requisite for the full play of the respiratory movements prevents or interferes with the further degeneration of this part of the skeleton. In the skull, many features and varieties are pointed out as being vestigial, atavistic, &c., but not much is added to our knowledge under this head. With regard to the limbs, the author agrees with Balfour and Dohrn in regarding the limbs of the vertebrates as out-growths from the primitive body segments, and thus believes in their originally segmented matter, and sees in this an argument for the origin of existing vertebrates from segmented invertebrate ancestors. In other words, these limbs, which in origin are polymerous, involve phylogenetically a certain number of body segments with their muscles and nerves; and these, in consequence of functional adaptation, must necessarily undergo different modifications in the different groups of vertebrates (p. 67).

It is suggested that the epicondylod holes occasionally seen in the humerus in man, and more frequently in some other animals, may be the result of incomplete fusion of the segments; and it is believed that in process of time the fore limb, originally a mere cervical appendage, has been shifted backwards to a more thoracic position; while the hind leg, originally a mere caudal appendage, has been moved forwards, slight changes in the corresponding metameric nerves being associated therewith. The apparent degeneration of the phalanges of the fifth and two adjacent toes gives rise to the suggestion of a prediction that the human foot may end by possessing only two two-jointed toes, the great toe and its neighbour.

It is remarked, and probably with truth, "that hardly a single human subject has been examined which has not shown some variation or other in the muscular system"; and this *embarras de richesses* is "considered in the following order; (1) retrogressive or vestigial muscles, such as the hinder. The *serrati*, with their fading connection, the *coccygei*, the *rectus* and *pyramidalis abdominis*, the *platysma* and other cutaneous muscles, the *palmaris* and *plantaris*; (2) muscles which, appearing only occasionally, are considered to be atavistic, such as the *cleido-occipitalis*, bundles connecting the pectoralis and the trapezius, the *sternalis*, &c.; (3) progressive muscles, such as those about the face and the hand. In the nervous system and the sense organs, the pineal and pituitary glands, Jacobson's organ, the plica lachrymalis, &c., are pointed out and traced as vestigial organs. Similar evidences of ascent and descent of ancestral or vestigial remains are traced in several viscera. In his concluding remarks, the author says:—

"In the course of Philogeny the body of man has undergone a series of modifications which still, in part, find expression in his Ontogeny. There are indications that changes in his organisation are still continuing, and that the man of the future will be different from the man of to-day."

"It follows from the above that in the course of a long geological period man has gradually lost a great number of advantages once possessed by his ancestors, and the question arises whether he has

acquired any others in exchange for those lost. This certainly is the case; and this indeed must have been so, otherwise the species *Homo* would have failed in the struggle for existence. We thus have a series of changes based (if we take only the most important organ into consideration) upon the unlimited capacity of development of the human brain. This one acquisition, supported by an increased functional efficiency of the hand, and by the development of articulate speech, has entirely compensated for the loss of the great series of advantageous arrangements mentioned above."

"This momentous change took place slowly, and only after great opposition. 'But what is it that actually initiates these various changes? what is their first cause?'" For the answer the author falls back "on the general law of selection" propounded by Charles Darwin, which may be summed up as follows: survival only of the fittest, transmissibility by inheritance, and the gradual improvement of what is advantageous from generation to generation till the highest possible degree of perfection is reached. The sufficiency of these agencies to bring about the ends we see is much questioned by some thoughtful and observant biologists; but into the arguments bearing on this interesting question we must not here enter.

Beiträge zur Physischen Anthropologie der Aino. II. Untersuchungen am Lebenden. Von Dr KOGANEI, Tokio, 1894.

IN our number for April 1894, we called attention to the first part of Dr Koganei's researches on the physical anthropology of the people of Yesso, which was devoted to the skeleton. He has now published in the second volume of the *Mittheilungen der medicinischen Facultät der Kaiserlich-Japanischen Universität zu Tokio*, a second series of his researches, embracing the external characters of living persons. The measurements were taken on 166 persons,—95 men, 71 women,—comprising Yezo—Sachalin—and Kuriten-Ainos. Their age was between 20 and 68 in the men, and 17 and 65 in the women. The characters of the integument are described: in colour it is different shades of brown, frequently with indications of red and at times shades of grey. Tattooing is not customary in the men, but is common in women between the eyebrows, around the mouth, and on the forearm and back of the hand. The hair is strong, abundant, and black. The mean height of the men is 1567 mm., the range being from 1410 to 1730 mm.; the mean of the women is 1471 mm., the range being from 1325 to 1620 mm. The head measurements give for the men 23·2 per cent. dolichocephalic; 61·1 per cent. mesocephalic; 15·8 per cent. brachycephalic: for the women, 11·3 per cent. dolichocephalic; 59·2 per cent. mesocephalic; 29·6 per cent. brachycephalic. The form of the eyes is more European than Mongolian. The nasal index is 68·0 for the men, 66·7 for the women. The memoir abounds in measurements of the face, body, and limbs, and comparisons with the corresponding dimensions in the Japanese are made.

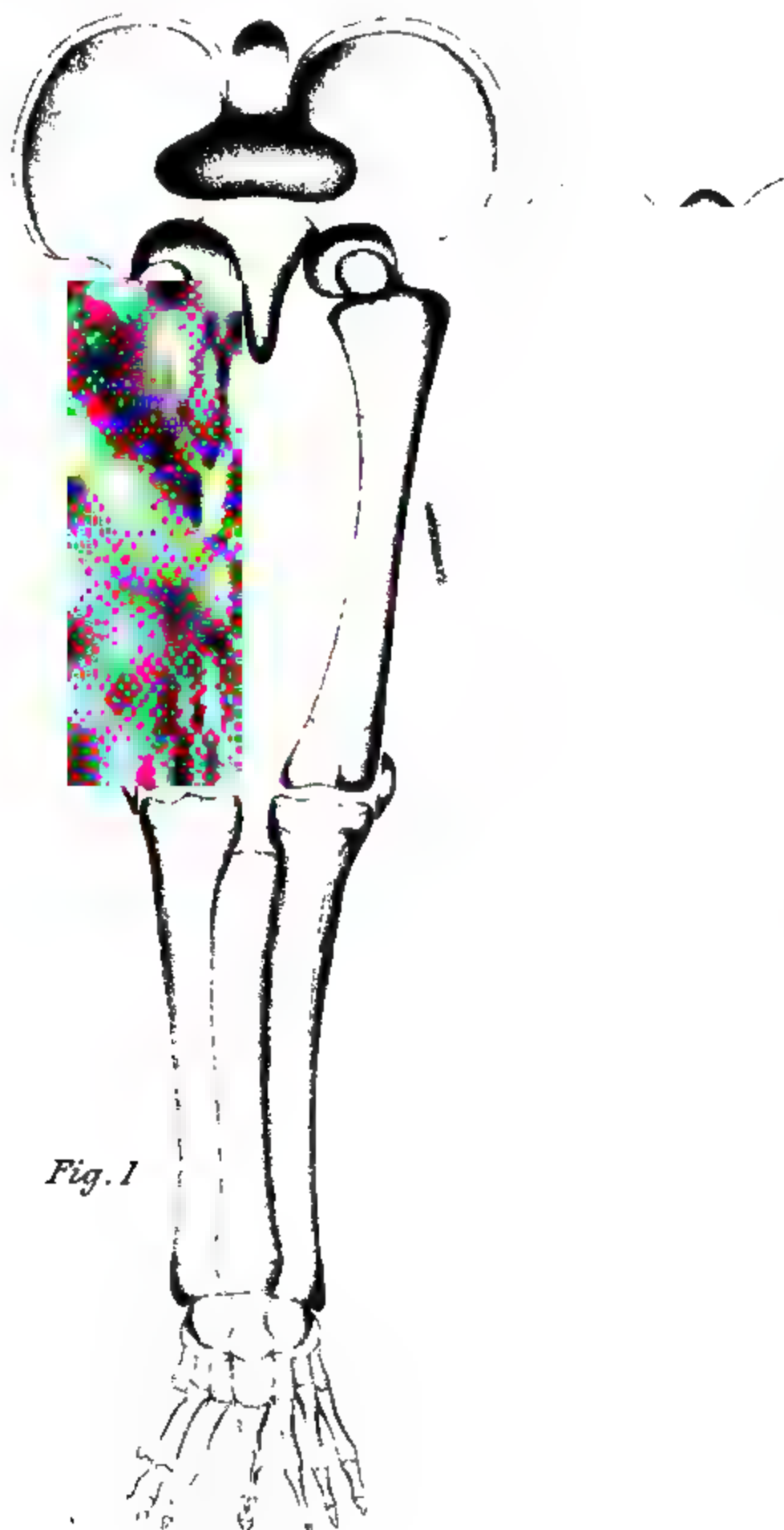
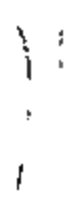


Fig. 1



Fig. 3.





Journal of Anatomy and Physiology.

ON THE FORMATION AND STRUCTURE OF THE OPTIC NERVE, AND ITS RELATION TO THE OPTIC STALK. By ARTHUR ROBINSON, M.D., *Senior Demonstrator of Anatomy, The Owens College, Manchester.* (PLATE VII.)

THE time has long since passed when the optic nerve was looked upon as corresponding, in all essential respects, with a typical nerve of the cerebro-spinal system, for conclusive proof was furnished, by the observations of the earlier embryologists, that the optic nerve is preceded by an outgrowth from the brain which extends to the retina, and which consists of epithelial cells, arranged in the form of a hollow stalk—the optic stalk of the embryo. It is also well known that this condition is only transient, the epithelial stalk being ultimately replaced by a fibrous nerve—the optic nerve of the adult. These simpler conditions have been generally recognised, but differences of opinion have arisen concerning the manner in which the epithelial stalk is converted into the fibrous nerve, some observers looking upon the stalk merely as a matrix through which the optic nerve fibres pass, in their course from origin to termination, whilst others have contended that the epithelial cells of the stalk are directly converted into the fibres of the optic nerve.

Later researches, aided by improved methods, have demonstrated the fallacy of the latter contention, and there can no longer be any doubt that the fibres of the optic nerve originate outside the limits of the optic stalk, and that the majority of them grow from the cells of the retina to the brain, whilst others probably arise in the brain and grow to the retina; nevertheless, English authors have hesitated to accept this con-

clusion, for the origin *in situ* is still adhered to in Foster's *Text-Book of Physiology* (4); and comparatively recently the late Professor Marshall wrote, "it is at present uncertain whether the fibres of the optic nerve of the rabbit are developed, *in situ*, from the walls of the tubular optic stalk, or whether, as seems far more probable, they arise in the retina and grow along the optic stalk to the brain" (12). In the last edition of Quain's *Anatomy*, however, Professor Schäfer (15) is very definite, stating clearly that the nerve fibres arise from the neuroblasts of the retina, and grow backwards to the brain. This being granted, so far as the majority of the fibres are concerned, the relation of the fibres to the optic stalk still remains to be decided.

According to W. Müller's (14) observations upon the lamprey, and Kölliker's (9) upon rabbits, pigs, and calves, the fibres grow amidst the cells of the stalk; and further confirmation of this process of growth is afforded by the observations of Keibel (8) upon reptiles, and of Froriep (5) upon cartilaginous fishes. Assheton, however (1), states that in the frog "the optic nerve is developed independently of the optic stalk, the nerve fibres lying along the posterior border of the stalk, and at first entirely outside it; but on the breaking down of the stalk, some of the nerve fibres grow in between the cells." If the condition which Assheton found in the frog is present in mammals also, then it follows that the sustentacular framework of the optic nerve of man may consist for the most part, like the framework of an ordinary cerebro-spinal nerve, of mesoblastic tissue surrounding and embedding the epiblastic nerve fibres; but if Müller's (14) and Kölliker's (9) statements are well founded, then the sustentacular tissue of the optic nerves in man and mammals must consist chiefly of epiblastic tissue derived from the primitive epithelial cells of the optic stalk; and as this is a matter of some morphological, and certainly of pathological, importance, the following record of a series of observations upon the development of the optic nerve, its relation to the optic stalk, and the formation of the sustentacular tissue in mammals may be of some interest.

The material used consisted of human embryos, and the embryos of cats, ferrets, sheep, rabbits, rats, and mice. In all

these animals the phenomena observed were essentially the same at similar stages; but as the series of rodent embryos is the most complete, the statements hereafter made are based more particularly upon the evidence furnished by that series, and sections of the optic nerves of rodents have alone been used for purposes of illustration.

Specimen I. (Fig. 1.)

A rat embryo 6·5 mm. long. Length of optic stalk ·367 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
·075	·097	·057	·072	·011	·014
·127	·098	·053	·072	·019	·021
·157	·098	·049	·081	·022	·030
·285	·121	·049	·106	·030	·045

The stalk was hollow throughout its whole length, and its walls consisted of nucleated protoplasm, indications of cellular segmentation being observable only near the canal and at the periphery; here and there, however, there were more clearly defined elements, which resembled closely the germinal cells of His (fig. 1). The nuclei were oval, and they lay at various levels in the walls of the stalk, with their long axes radiating from its cavity.

The measurements given in the above table show that the stalk was thinnest near the retina, and thickest at its cerebral end, the increase being due chiefly to enlargement of the walls, and more especially of the ventral wall, the cavity varying but little.

Specimen II. (Figs. 3, 4, 5.)

A rat embryo 8 mm. long. Length of optic stalk ·582 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
·022	·083	·030	·064	·005	·039
·075	·064	·017	·057	·007	·032
·187	·057	·011	·045	·005	·022
·285	·049	·011	·049	·005	·022
·457	·076	·028	·068	·011	·034

The measurements show that the stalk decreased in size from the retina to beyond the centre of its length, and then increased again towards its cerebral end. It was thinner throughout the whole of its length than the younger embryo, and the reduction of the thickness was apparently due, for the most part, to the reduction of the lumen of the stalk, for the walls, and more especially the ventral wall, were generally thicker in this than in the younger specimen.

Near the retina the wall of the stalk was compressed dorso-ventral and its lower surface was grooved, forming a sulcus beneath which the central artery of the retina was placed. As in the earlier stage, cell outlines were not clearly distinguishable. In transverse sections the nuclei were oval, and in the cerebral portion of the stalk they lay at varying depths in the walls; but, whilst in the retinal section of the stalk, in the dorsal and lateral walls, a similar irregular arrangement was present, some of the nuclei lying near the periphery, and others near the central boundary, in the ventral wall a more definite arrangement prevailed (figs. 3 and 4), for in this situation, though the nuclei were not placed all in one uniform plane, they were all situated at some distance from the ventral boundary, that is, they lay, as a body, nearer the centre than the periphery of the stalk.

In the ventral wall of the stalk, subjacent to the layer of nuclei, numerous minute dots were observable. Transverse sections, and longitudinal sections of similar and of somewhat later stages (fig. 2), showed clearly that the dots in question represented transverse sections of young optic nerve fibres, which at this period, and for some time afterwards, were found exclusively in the ventral wall of the stalk. In this specimen, however, neither longitudinal nor transverse sections afforded any distinct indication of the exact relationship of the developing nerve fibres to the protoplasmic substance of the stalk. The fibres were only distinguishable for a distance of about .112 mm. inwards from the retina towards the brain (fig. 3). They were most numerous near the retina, and none were visible at the cerebral end of the stalk.

The peripheral boundary of the stalk was clearly defined, but

it was not possible to demonstrate a distinct external limiting membrane.

Specimen III. (Figs. 6, 7, 8.)

A rat embryo 9 mm. long. Length of optic stalk .615 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
.043	.102	.045	.087	.026	.042
.085	.088	.026	.076	.014	.042
.187	.079	.022	.064	.007	.037
.212	.076	.014	.064	.005	.038
.314	.079	.022	.068	.007	.038
.457	.083	.034	.079	.015	.038

The stalk was thicker and longer than in the preceding stage, and the increase in the thickness was due not so much to increase of the lumen of the stalk, which was but slightly enlarged, as to the growth of its walls, and more especially of the ventral wall, in which a layer of nerve fibres was now distinctly visible (figs. 6 and 7). The nerve fibres were collected into small perpendicular groups, separated from each other by fine strands of condensed protoplasmic tissue, which were continuous dorsally with the protoplasm surrounding the nuclei of the ventral wall of the stalk, and ventrally with the external limiting membrane, which was quite distinct. The majority of the nuclei in the ventral wall of the stalk lay dorsal to the layer of nerve fibres, but here and there nuclei were observable in the protoplasmic strands between the bundles of nerve fibres; there could be little doubt, therefore, that the strands were nothing else than compressed cells, and portions of cells, extending in a palisade-like manner from the canal to the periphery, and that they had been defined, compressed, separated, and possibly stretched by the interpolation between them of nerve fibres growing along the stalk. At this stage there was a continuous layer of fibres from the retina to the brain, but the fibres were more numerous in the retinal portion of the stalk (compare figs. 6 and 8).

The external limiting membrane was closely connected with the radiating protoplasmic strands, and by these it was united

to an inner limiting membrane bounding the lumen of the canal; moreover, the external limiting membrane was continuous externally with the outer wall of the retina, and internally with the outer bounding membrane of the thalamencephalon.

Specimen IV. (Fig. 9.)

A rat embryo 10 mm. long. Length of optic stalk .600 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
.037	.146	.026	.110	.007	.091
.075	.146	.015	.114	.007	.091
.187	.129	.022	.129	.015	.094
.562	.152	.007	.117	.005	.079

The stalk was hollow throughout its whole length, but the cavity was smaller than in the preceding stage, the diminution of its calibre being most marked where it is passing through the cartilaginous wall of the skull, at a point .562 mm. from the retina.

The external limiting membrane, and its connections with the protoplasmic processes of the cells of the stalk, were better marked than in the younger specimens, and the internal limiting membrane was also more distinct. The arrangement of the nuclei was more irregular than in the earlier stages (fig. 9). The dorsal portion of the stalk was still formed by a layer of protoplasm in which was embedded one row of spherical nuclei; in the ventral wall there was a single layer of rounded nuclei lying close to the cavity, but this wall was no longer divisible into a layer of nuclei and a layer of nerve fibres. On the contrary, the nuclei were scattered throughout its whole thickness, lying embedded in the nodes of the protoplasmic reticulum, which extended from the canal to the periphery. The main protoplasmic strands radiated from the canal to the external limiting membrane, but they were united to each other by fine anastomosing processes: and the meshes of the reticulum thus formed were occupied principally by fine nerve fibres which, at this stage, were scattered throughout the greater part of the thickness of the ventral wall of the stalk.

The ventral wall of the stalk constituted by far the greater part of the whole, the canal being displaced dorsally; and the dorsal wall contained only a single layer of nuclei.

As in the preceding stage, the thickness of the stalk diminished at first as the distance from the retina increased, but this diminution was not continuous, for the cerebral portion was also thicker than the intermediate part; but whilst the greater thickness of the retinal section was due to the ventral wall, that of the cerebral portion was caused by the dorsal wall.

Specimen V. (Figs. 10 and 11.)

A rat embryo 11 mm. long. Length of optic stalk .787 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
.037	.096	.034	.076	.007	.053
.187	.091	.011	.091	.013	.057
.337	.076	absent.	.091	absent.	...
.487	.077	.015	.095	.007	.057
.697	.144	.028	.079	.011	.053

The stalk was longer but not so thick as in the 10 mm. embryo, and the reduction of the thickness was due to differences in the thickness of the walls, not to mere diminution of the lumen, which was enlarged as compared with the younger specimen, except in that portion of its extent which lay between .262 and .487 mm. from the retina, where the cavity was obliterated and the stalk solid (fig. 11).

The structural details were in most respects similar to those described in the next younger stage. The ventral wall was relatively very thick, and in it were many scattered nuclei.

The protoplasmic groundwork was more distinct than in the younger specimens, and the groups of nerve fibres were somewhat larger and more numerous; moreover, they were no longer limited to the ventral wall, but were present also in the lateral walls.

Where the canal was still present, its dorsal wall contained one, or at the most two, rows of nuclei; and where the canal was no longer present, its position was indicated (fig. 11) by a group of nuclei, arranged somewhat irregularly, but with a tendency

to radiate from the centre of the stalk; and these nuclei were embedded in a granular protoplasm, which was not divided into distinct cell territories.

Specimen VI. (Fig. 12.)

A mouse embryo 14 mm. long; length of optic stalk, .975 mm.

Distance of Section from Retina.	Sagittal Diameter.		Vertical Diameter.		Ventral Wall of Canal.
	Stalk.	Canal.	Stalk.	Canal.	
mm.	mm.	mm.	mm.	mm.	mm.
.150	.148	...	.171	...	...
.600	.159	...	.140	...	...

This specimen was stained with logwood and eosin, a combination of stains which exhibits the reticulum much more clearly than the nerve fibres.

The stalk was solid through its whole length, the only indication of the previously existent canal being a core of granular nucleated protoplasm, devoid of nerve fibres.

The strands of the protoplasmic reticulum were finer than in the earlier stages, and the meshes larger. The nuclei towards the centre were arranged more or less radially, but many of those lying near the periphery were elongated parallel with the surface of the stalk.

The external limiting membrane was still quite distinct, and it retained its intimate connection with the internal sustentacular reticulum, but its external surface was more closely covered with mesodermal cells than in the earlier stages. There was no evidence, however, that mesodermal tissues had as yet penetrated the substance of the stalk, and there was no clear indication of the presence of blood-vessels, the nutritive supply being derived, apparently, entirely from lymphatic fluids, although the stalk was practically converted into the fibrous optic nerve.

REMARKS.

On the Relation of the Optic Nerve to the Optic Stalk, and on the Sustentacular Tissue of the Nerve.

In all the specimens examined where nerve fibres were present they lay within the area of the stalk, occupying, therefore, a

very different position to that described by Assheton in the case of the optic nerve fibres of the frog (1): the conditions met with in all my specimens were confirmatory of the statements which have been made by W. Müller (14) and by Kölliker (9) concerning the general relations of the optic nerve fibres to the optic stalk.

As the fibres grow from the nerve cells with which they are connected, they pass into the substance of the stalk, forcing their way between its constituent parts, and ultimately acquiring an intercellular position: it is not, however, possible to state definitely that they possess such a position on their first entry into the stalk, for there are indications that in the early stages the cell territories of the stalk are not defined, or, in other words, that the stalk is a hollow nucleated plasmodium, and that the separation of the protoplasmic mass into cell areas is possibly initiated by the entrance of the optic nerve fibres into it. In support of this possibility, it is to be remembered that it is only as the nerve fibres increase in number that the cell territories become defined, and that the constituent cells are never completely isolated from each other, for they remain connected by anastomosing processes which limit the areas through which the nerve fibres pass; but, however this may be, there can be no doubt about the final result, which is that the nucleated protoplasmic walls of the optic stalk become directly converted into the sustentacular tissue of the optic nerve, exactly in the same manner that the spongioblasts of the spinal cord and the brain are converted into the neurospongial substance; and, in the first instance at all events, the mesodermal tissue takes no part in the formation of the optic nerve, though at a later period a mesodermal invasion of the nerve must occur in association with the ingrowth of vessels into the nerve substance.

It was noted in the description of the youngest specimen that certain cells, closely resembling the germinal cells of His, were visible in parts of the stalk: it was not possible to obtain any clear indication of their fate, but there was no evidence that they became converted into neuroblasts, and, presumably, they also take part in the formation of the sustentacular tissue.

Whilst the optic nerve fibres are invading the optic stalk,

the latter structure undergoes changes in size, constantly increasing in length with the growth of the embryo, but undergoing alterations of thickness, which are due partly to increase and diminution of its lumen, and partly to changes in the walls of the stalk; and the latter, in their turn, are dependent, on the one hand, upon alteration of the cellular constituents of the stalk, and, on the other, upon the invasion of the stalk by the optic nerve fibres.

The canal is at first relatively large (fig. 1): during the early period of the nerve fibre invasion it undergoes both a relative and an absolute diminution in calibre; this is succeeded by an increase, which in its turn is followed by a diminution, and this second diminution is progressive, terminating in the complete obliteration of the canal (fig. 11).

In the earliest stages the canal is relatively central, but afterwards, as the ventral wall increases rapidly whilst the dorsal remains comparatively unaltered, the canal is displaced to the dorsal side of the stalk, and it retains this position till the period of the obliteration, when, as the cavity disappears, the inner ends of the cells which immediately surround it are moved towards the centre of the stalk, where their remains form for a time a distinct granular core, from which protoplasmic strands radiate to the periphery.

During the greater part of the period of its existence the cavity of the canal appears to be bounded by a limiting membrane, formed by the fused extremities of the surrounding cells; and as the canal is obliterated, this membrane gradually disappears, and no trace of it is discoverable in the stalk, which has become solid.

The causes which bring about the disappearance of the canal are obscure. The obliteration is not due to mere stretching of the stalk, for the canal enlarges for a time, whilst the length of the stalk is still increasing. Pressure of the cranial walls cannot be considered as an important agent, for although in 10 mm. embryos the stalk is smallest where it is passing through the cartilaginous cranial wall, the actual obliteration of the lumen takes place, in the first instance, where the stalk is surrounded by the ocular muscles and beneath the nasal nerve, that is, in a situation where it is inconceivable that any serious

pressure can exist. It appears at the first sight that the pressure of the invading nerve fibres may possibly play an important part in bringing about the obliteration, but that this is not necessarily the case is proved by the increase of the calibre of the canal, which occurs simultaneously with the extension of the invasion in 9 mm. embryos. We are forced, therefore, to assume that the obliteration of the lumen of the canal is brought about by developmental changes in growth and relationship of the constituent parts of the stalk, and with these is associated the invasion of the optic nerve fibres.

Summary.

In mammals the optic stalk becomes converted into the optic nerve by the transformation of its protoplasmic substance into retiform sustentacular tissue, and by the passage of nerve fibres through its walls, the nerve fibres being protected and supported by the external limiting membrane of the stalk, and by the reticular framework formed by the modification of its walls, the transformation from the stalk to the nerve being associated with the disappearance of the cavity of the stalk.

On the Origin of the Optic Nerve Fibres and their Course through the Optic Stalk.

The opinion held by Lieberkühn (10), Manz (11), and Balfour (2), that the optic nerve fibres arose *in situ* by the differentiation of the walls of the stalk, was opposed by a number of the earlier observers, who differed amongst themselves, however, with regard to the seat of origin of the fibres, Kölliker (9) and His for a time (6) believing that they were formed in the brain and travelled centrifugally to the retina, whilst W. Müller (14) located their origin in the retina.

Kölliker based his opinion upon his discovery of fibres in the optic tracts before they were present in the optic nerves, but he pointed out, at the same time, that in all cases in which he had found fibres present in the stalk, they extended throughout its whole length; evidently, therefore, he had not traced their progress through the stalk. It appears certain, however, from Cajal's observations (3), that some of the optic nerve fibres arise

in the brain and pass centrifugally through the stalk; but the more recent observations of His upon human embryos (7), and the investigations of Keibel (5) upon reptiles, Froriep (5) upon cartilaginous fishes, and Assheton (1) upon amphibians, all tend to the conclusion that the majority of the optic nerve fibres rise in the retina and pass centripetally to the brain; and this conclusion is strongly supported by the specimens at my disposal, for not only are the nerve fibres at their first appearance in the stalk present only in its retinal portion, but in the later stages, when they are distributed throughout the whole length of the stalk, they are most abundant near the retina. It must be noted, however, in certain stages of development, 8 and 9 mm. embryos, that the two extremities of the stalk are thicker than its intermediate portion. In the 8 mm. embryo the greater thickness of the ventral wall in the retinal part of the stalk must to some extent depend on the presence of the invading nerve fibres; but in the cerebral section of the stalk, nerve fibres are not recognisable, and the greater thickness in this region can only be due to greater growth of the walls associated with some enlargement of the canal. In the 9 mm. embryo, however, nerve fibres are present throughout the whole length of the stalk, and it is possible that the increased thickness at the two terminal sections of the stalk may in this case be due to the presence of additional nerve fibres, in which case some of those in the cerebral section must have grown into the stalk from the brain, as Cajal's observations seem to indicate; but the great preponderance of the fibres in the retinal portion in the earlier stages is sufficient evidence that the majority of the fibres originate in the retina.

When the invasion of the stalk first commences, the fibres are limited to the ventral wall, that is, to that portion of the stalk which is more directly continuous with the inner wall of the optic cup in which the nerve fibres originate, whilst the dorsal part of the stalk, which is more directly continuous with the retinal pigment layer, is for a time entirely devoid of nerve fibres. As the fibres increase in number, they gradually invade the lateral walls of the stalk, but it is not until the actual obliteration of the canal occurs that they penetrate the dorsal wall, an occurrence which is associated with the displacement of the

nuclei around the margins of the canal towards the centre of the stalk.

The separation of the protoplasmic walls of the stalk into a number of radial anastomosing strands is undoubtedly due to the invasion of the nerve fibres, and the attenuation and elongation of the strands is most probably dependent on a similar cause; but the contraction of the diameters of the stalk which occurs in 11 mm. embryos appears to indicate that the protoplasmic reticulum remains possessed, for a time at least, of a contractile power sufficient to bring about the condensation of the stalk, and it is noticeable that such a contraction occurs at the period when the hollow stalk is becoming converted into the solid nerve.

On the Relation of the Optic Nerve and the Retina to the Brain.

It is generally admitted that the retina is merely an outstanding portion of the central nervous system, peculiarly modified for the performance of a particular function; but it is not so generally recognised that the connection of this sensory organ with the central system is never lost, and in this respect the retina differs from all the ordinary sensory ganglia of the cerebro-spinal system except the olfactory bulb, and it differs from the latter in that it is never associated by nervous elements with modified epithelial cells of the surface ectoderm. It is therefore the only portion of the central system upon which external influences act directly, unless we are to assume that the lens and the surface epithelium of the cornea play a part, in relation to the retinal elements, which is in some way comparable to that performed by the epithelium of the skin in relation to the terminal extremities of the sensory nerve fibres; and even if that be the case, still the continuous connection of the retina with the more central parts of the nervous system is sufficient to differentiate it from the ordinary sensory ganglia, which are either separated from the deeper layer of the surface ectoderm, or are outgrowths from a neural crest, and only attain their connection with the cord or brain by ingrowing fibres which pass through, and are more or less mixed with, a greater or less amount of mesoderm; whilst the optic nerve fibres in their

course, from origin to termination, traverse only a part of the central nervous system, never at any period of their development lying outside its limits; indeed, the optic nerves themselves are as much parts of the central system as any of the white columns of the brain or spinal cord, for their fibres lie within the outer limiting membrane of the system, and their sustentacular framework is formed by the differentiation of the primitive ectodermal tissue of the walls of the central canal. The retina is therefore a portion of the brain wall specially situated and modified in adaptation to the proper performance of its function; and inasmuch as it is an outgrowth of the ventral part of the lateral wall of the thalamencephalon, the retina may be looked upon as a modified basal ganglion, and the optic nerves are association bundles bringing it into relationship with other parts of the brain. This subject has recently been dealt with by Dr T. K. Monro (13), who, considering it principally from a pathological standpoint, has arrived at conclusions similar to those which are indicated by embryological evidence.

DESCRIPTION OF PLATE VII.

Fig. 1. A transverse section of the optic stalk of a rat embryo 6.5 mm. long: distance of section from retina .285 mm., vertical diameter of section .106 mm., transverse diameter of section .121 mm.

Fig. 2. A vertical section of a portion of the retina and the optic stalk of a mouse embryo, showing the passage of nerve fibres from the retina into the ventral wall of the stalk.

Figs. 3, 4, and 5. Transverse sections of the optic stalk of a rat embryo 8 mm. long: fig. 3, distant from retina .022 mm., transverse diameter .083 mm., vertical diameter .064 mm.; fig. 4, distant from retina .075 mm., transverse diameter .064 mm., vertical diameter .057 mm.; fig. 5, distant from retina .187 mm., transverse diameter .057 mm., vertical diameter .045 mm.

Figs. 6, 7, and 8. Transverse sections of the optic stalk of a rat embryo 9 mm. long: fig. 6, distant from retina .043 mm., transverse diameter .102 mm., vertical diameter .087 mm.; fig. 7, distant from retina .187 mm., transverse diameter .079 mm., vertical diameter .064 mm.; fig. 8, this section is a little oblique, and is situated at the junction of the stalk with the thalamencephalon; transverse diameter .140 mm., vertical diameter .095 mm.

Fig. 9. A transverse section of the optic stalk of a rat embryo 10 mm. long: distant from retina .037 mm., transverse diameter .146 mm., vertical diameter .114 mm.

Figs. 10 and 11. Transverse sections of the optic stalk of a rat embryo 11 mm. long: fig. 10, distant from retina $\cdot 187$ mm., transverse diameter $\cdot 091$ mm., vertical diameter $\cdot 091$ mm.; fig. 11, distant from retina $\cdot 337$ mm., transverse diameter $\cdot 076$ mm., vertical diameter $\cdot 091$ mm.

Fig. 12. A transverse section of the optic stalk of a mouse embryo 14 mm. long: distant from retina $\cdot 600$ mm., transverse diameter $\cdot 148$ mm., vertical diameter $\cdot 171$ mm.

C, canal of stalk; D, dorsal; L, lateral; N, nerve fibres; O, optic cup; R, reticulum; Ret, retina; T, thalamencephalon; V, ventral.

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ON THE PANCREAS OF THE HEDGEHOG DURING
HIBERNATION. By E. W. CARLIER, M.D., *Physiological
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(Read before the Scottish Microscopical Society, Jan. 18, 1895.)

THE animal, a large one, at the time of death was in a profound state of hibernation, and had been in this condition for some time. I was not a little astonished, therefore, on examining the sections, to find the pancreas in a more or less active state, believing, as I did, that the bile was the only secretion poured into the alimentary canal during winter sleep.

Methods.—The animal was killed with chloroform, unrolled, and the abdomen opened as rapidly as possible. The gland after removal was cut into slices from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, and placed at once into a saturated watery solution of mercuric chloride in normal saline, at the body temperature, as recommended by Martin Heidenhain.¹ The tissues, after remaining in this fluid for twenty-four hours, were well washed in running water and taken up the alcohol series, through chloroform into paraffin. Sections were cut of a thickness of $1\ \mu$ to $5\ \mu$, fixed to albuminised slides (Mann's method)² and stained in (a) Mann's methyl-blue eosin long method;³ (b) Mann's methyl-blue eosin short method; (c) Mann's toluidin blue eosin method,⁴ for nuclear structure; (d) Ehrlich's original triacid; (e) Ehrlich's⁵ acid hæmatoxylin eosin method; (f) M. Heidenhain's⁶ hæmatoxylin-iron-alum methods for nuclei and protoplasm, and for his subtraction method for centrosomes, using now Bordeaux red, now Mann's methyl-blue eosin long method as the preliminary stain.

¹ *Ueb. Kern u. Protoplasma*, 1892, p. 113.

² *Anat. Anzeig.*, Jahrg viii. (1893), p. 442.

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⁴ *Proc. Scott. Micro. Soc.*, vol. i. p. 163.

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The sections were all subsequently cleared in xylol and mounted in balsam. They were examined with Leitz $\frac{1}{2}$ oil immersion objective, and No. 12 compensating eyepiece.

Fearing lest the strong corrosive sublimate solution might fix the tissues at the periphery of the slices so firmly that it would fail to penetrate the deeper parts with sufficient rapidity to fix the cells before they had time to become altered, I injected another hibernating hedgehog through the aorta, immediately after death, with Mann's picro-corrosive solution, sp. gr. 1020, as recommended by him,¹ and subsequently treated the tissue as above detailed, but found that the first set of tissues had been quite as well fixed as the injected ones, and that M. Heidenhain's corrosive had successfully penetrated the thin slices immersed in it.

The Cells.—The cells which line the acini in a single layer exhibit, as first pointed out by Heidenhain (12) and subsequently confirmed by many investigators, two well-marked zones,—an inner, clear zone, containing granules of ferment; and an outer, dense zone, readily stainable in hæmatoxylin and carmine, which contains the single rounded nucleus. Heidenhain also observed that the relative size of these two zones varied from time to time, the inner one diminishing and the outer one increasing during secretion, whilst the reverse occurred during the resting condition. This phenomenon depends on the disappearance of the granules from the protoplasm during activity, and their subsequent reproduction in the period of rest that immediately follows it. He also noticed the curious fact that prolonged fasting caused the disappearance of some of the granules.

In the preparations I examined, cells in all stages of rest and secretion were observed; some appeared crowded with granules, stained deep red with eosin and other dyes for which they have affinity. The granules occupied almost the whole cell, the outer zone being reduced to a narrow strip containing the nucleus, which is rich in chromatin and small in size. This condition was especially well seen at the margins of the lobules, as described by ver Eecke (43), and also by Harris and Gow (11). In other regions, again, the cells were almost or entirely devoid of granules, the clear inner zone being much reduced and the outer

¹ *Proc. Scott. Micro. Soc.*, vol. i. p. 155.

zone correspondingly enlarged, as was also the nucleus situated within it, which appeared swollen and clear, and frequently exhibiting a large nucleolus, somewhat excentrically placed.

Cells in all conditions between these two extremes could be seen throughout the gland.

Heidenhain (12) was the first to give the name of zymogen to these granules, which vary much in size in different cells; they are confined to the inner zone, and between them, when not too crowded, the fine spongioplasm described by ver Eecke may be clearly seen as a fine indefinite network stained of a faint cobalt blue colour in sections treated by Mann's long method.

The hyaloplasm surrounding both network and granules remained unstained. The protoplasm of the outer zone presents a finely granular appearance, owing to the dense manner in which its spongioplasm is arranged, but there is no evidence of a cord-like arrangement described by Kühne and Lea (20) and others, which is artificial, and due to hardening in Müller's fluid and chromic salts, as pointed out by ver Eecke (43). The two zones are sharply marked off, the dense spongioplasm of the outer suddenly giving place to the fine network of the inner zone. A definite cell membrane surrounds the cell.

The nucleus is single, spherical in shape, and varies greatly in appearance in different cells, being full of chromatic material in cases where the cells are full of granules, and stained so deeply that its finer structure is greatly obscured; nevertheless, a curious oval or rounded vacuole may be observed in many of them, situated at no great distance from the nucleolus. In cells in which secretion has begun or been in progress for some time, the nuclei stain less deeply, and exhibit a well-marked red staining nucleolus, in which traces of an endonucleolus can sometimes be discerned. This nucleolus is surrounded by a dense mass of chromatin (karyosomes of Orgata (35) and others), varying in amount in different cases, from which fine chromatin threads radiate outwards to join with the masses of chromatin situated, as in most cells, immediately beneath the nuclear envelope, which is thick and well marked. On these radiating threads occasional karyosomes may be seen. The remainder of the nucleus consists of clear unstainable nucleoplasm, in which it is not rare to see several small red staining particles.

In cells from which most of the zymogen granules have disappeared, the nucleus is usually much larger, clearer, and poor in chromatin, the mass round the nucleolus being reduced to a minimum, and indeed often disappearing altogether; the nucleolus also appears much larger in many cases, has a swollen watery look, especially in the centre, and often almost touches the nuclear envelope.

In many cells outside the nucleus, an accessory nucleus can be faintly seen; it varies in shape, appearing sometimes as a body crescentic in optical section, sometimes as a flattened sphere, and sometimes again exhibiting other forms. It is usually of some size, varying from half that of the nucleus to about the same size; it stains like the neighbouring dense granular spongioplasm, from which it is difficult to distinguish it. This body was discovered by Nussbaum (34) and studied by Platner (37), who states that it is produced by strangling of a nucleus containing two nucleoli—this is confirmed by Laguesse (22)—the lower part separating to form the accessory nucleus, and subsequently undergoing various transformations in the protoplasm, degenerating and ultimately becoming transformed into zymogen granules. Orgata (35) and ver Eecke (43) believe that part of this body, which they derive from the nucleus and karyosomes by emigration, becomes transformed into a new nucleus for the cell, the remainder being converted into zymogen. I have diligently searched for some indication of a transformation of these accessory nuclei into true new nuclei, but have entirely failed to find any, nor have I seen any evidence of the extrusion through the granular zone of old nuclear bags, as described by ver Eecke.

One or two centrosomes are usually present, either widely separated or close together, each surrounded by a clear zone of archoplasm, best seen in specimens stained by M. Heidenhain's subtractive method. In one case in a resting cell I have clearly seen two large centrosomes separated from one another by a short interval, bridged across by threads arranged in a spindle. On the outermost threads of this spindle appear two short rod-shaped bodies, parallel with one another, which, looked at in the light of a recent paper by R. Lauterborn (27), on the division of diatoms, may be an indication of the formation of the central

spindle derived from a body extruded from the nucleus. I described a similar spindle occurring in a resting cell of the cortical part of the suprarenal body of the rat, in an unpublished paper read before the *Scottish Microscopical Society* in 1893.

I believe that some of the smaller particles described by Orgata (35) and ver Eecke (43) as occurring in the outer zones of the pancreas cells, to be these centrosomes which are not mentioned by either author. With them I can very well believe in the passage of the nucleolus through the nuclear wall into the surrounding protoplasm, as I described a similar phenomenon occurring in the hibernating gland (5), though this does not appear to happen very frequently, while the passage of nucleolar particles is frequent enough, the nucleolus remaining behind. It is well known that nucleoli do divide in the nucleus, and that some of their substance is then passed out and may undergo further division in the protoplasm, but I can see no evidence of their conversion into accessory nuclei, which have quite a different appearance; but that they may take part in the formation of zymogen granules is possible, though I have not been able to convince myself of the fact. I think they more probably break down in the protoplasm, as those observed by me in the hibernating gland undoubtedly do. With regard to some of the extra-nuclear bodies being derived from leucocytes or phagocytes that have migrated into the cell, I can see no evidence whatever; I do not think it at all likely to occur, as I know of no case of migration of white blood corpuscles, much less of the larger phagocytes into healthy gland cells.

The nature of the granules is very important. Both Langerhans (25) and Giannuzzi (9), who used osmic acid—which blackens the granules—considered them to consist of fatty material. Orgata (35), 1883, believes that they consist of a ferment or its antecedent, and that they are derived indirectly from the nucleus. Ver Eecke (43), 1893, supports this view, stating in addition that they arise from the hyaloplasm of the cells, which in its turn has its origin in the blood plasma; he also derives them in part from leucocytes and phagocytes. On the other hand, this nuclear theory is denied both by Nickolaides (33), 1890, and Laguesse (22), 1893. Arnozan and Vaillard (1) (1884) find that the granules disappear in Müller's fluid, but are retained in osmic

acid; they find that thin sections of fresh pancreas left for twenty-four hours under a bell jar digest themselves, and that this property was not lost if the gland had been previously fixed in alcohol, provided water was added to the preparation before leaving it. After this auto-digestion is completed, little acicular crystals make their appearance, grouped in sheaves, which Robin and Claude Bernard (2) looked upon as consisting of sulphate of calcium (leucin and tyrosin?).

Lewaschew (29) (1885) found that in dogs starved for five days the cells were full of granules, but that on making an extract of the glands in the usual way, he was unable to digest fibrin with it. He concluded, therefore, that there was no trypsin present, and that the granules observed could not be material for the formation of that ferment, and that zymogen is only one of the constituents of the granules, perhaps merely adhering to them, and that it could be used up without causing their disappearance; however, no ferment is ever obtainable when the granules are absent. R. Heidenhain (13), thinking that another explanation might be possible, namely, that the alteration produced in the cell protoplasm by fasting might prevent the granules from being converted into ferment, undertook to reinvestigate the matter, and not only made extracts in the usual manner, but also extracted the fresh gland with acetic acid; he failed, however, to produce digestion by either method, and therefore confirms Lewaschew's statement. A. Dastre (7), in 1893, studied the ferments of the pancreas, and concluded that the amylolytic and tryptic ferments were physiologically distinct, and believes that the amylolytic ferment is produced as such, while the trypsin is first secreted as a zymogen, which would only acquire its fermentative properties by a prolonged contact with the products of the activity of the gland cell. In the same year Carvallo and Pachon (6) starved pigs for five days, giving neither food nor water, and extracted the pancreas, adding a little sodium carbonate to the extract with the fibrin. They found that such extracts prepared in four different ways digested fibrin well, which is quite contrary to the classical experiments of Schiff and Herzen. To this Herzen (16) replies, that whereas in actively secreting animals the pancreatic extract digests fibrin in a few hours, that made from fasting animals

acts only after some ten to twenty-four hours. Dastre (7) remarks on the same occasion that his experience coincides with that of Carvallo and Pachon, and believes that during digestion is already formed trypsin in the glands, whilst during fasting only zymogen is stored up.

I believe the zymogen to be almost entirely derived from the hyaloplasm of the cells. When the granules are about to be secreted they swell up and lose their homogeneous appearance, the centre becoming lighter than the circumference; they are then moved towards the lumen of the acinus and disappear probably by solution inside the cell, because none of them are visible in the channels between the cells, and because in the smaller ducts leading from the acini the secretion, when present, has a homogeneous appearance. In some of the larger ducts, however, distinct granules may be clearly seen; they stain like zymogen granules, but are usually larger, and are due, I think, to coagulation of proteid substances, which, as is well known, often assume a granular appearance when fixed by corrosive sublimate.

This whole question, therefore, requires further investigation.

During secretion the cells become smaller—this is especially due to diminution in the size of the inner zone,—and the tips of the cells separate from one another, transforming the lumen of the acinus from a mere chink to a wide stellate channel; the outer zones of such cell occupy more space and stain more deeply than in resting cells; this deeper staining probably results from the imbibition of blood plasma by the outer zone. The nucleus enlarges, becomes clear, and probably less rich in chromatin, though this apparent diminution of chromatic material may be due to dispersion over a larger surface—certainly that aggregated round the nucleolus diminishes in amount, and the nucleolus becomes much more clearly defined. Finally, the nucleus again diminishes in size, accompanied by a decided enlargement of the nucleolus, which assumes a less concentrated appearance.

It is towards the centre of the lobules more especially that the greatest activity is visible in my specimens, the cells here being almost devoid of granules, especially round the openings

of the intermediate ducts into the acini. At the margins of the lobules, on the other hand, *i.e.*, in the parts furthest from the ducts, the activity appears to be *nil*, or only very slight indeed, for in that region the cells are packed with granules. Probably the gland activity, taken as a whole, is very feeble during hibernation, and the granules, when once discharged, do not appear to be very readily reproduced.

The Ducts.—Turning now to the ducts, I find that they have the usual structure, consisting in the larger tubes of a lining of nucleated, clear columnar cells in a single layer. The cells exhibit a clear hem of considerable thickness, between which and the rounded nucleus the spongioplasm is arranged in fine rods, vertically placed and closely crowded; these rods appear beaded at intervals, probably where fine cross strands run between them. This is best made out in specimens stained by Mann's long method, followed by Heidenhain's iron alum, the little rods appearing almost black in the surrounding faintly stained hyaloplasm. The cells are united together by cement substance only near their free ends; it appears as little rounded thickenings near the tips of the cells, a little black dot appearing at the level of the base of the clear hem between each two cells; an occasional leucocyte may be seen in the act of migration through this epithelium.

The cells are placed on the subjacent, somewhat dense connective tissue, without the intervention of a basement membrane, agreeing therefore in this with the description given by Giannuzzi (9) and by Harris and Gow (11). Klein (19) and most other investigators have described an endothelial basement membrane upon which the cells stand, and they believe this to be continuous with a similar structure surrounding the acini, which, with Harris and Gow, I have also failed to find.

I have seen no trace in the hedgehog of a muscular sheath surrounding the larger ducts, though it exists in some other animals, as stated by Klein (19); but somewhat large mucous glands are situated here and there in the connective tissue surrounding the largest ducts, whose walls are pierced by those of the mucous glands, as described by Henneage Gibbes (15), and which would result in the admixture of a certain amount of mucus with the other substances contained in the pancreatic

secretion. In my specimens I see no evidence of activity of these glands during hibernation, their cells being filled with fine granules.

As the calibre of the ducts diminishes, the epithelial cells become smaller and flatter, until, near the acini, they are so thin that their spherical nuclei bulge into the lumen, and impart to it a sinuous appearance. These are followed by the spindle-shaped "centro-acinar" cells described by so many authors (Heidenhain (12), Langerhans (25), Giannuzzi (9), Boll (3), von Ebner, Pflüger (36), Saviotti (40), Arnozan and Vaillard (1), Renant (39), Latschenberger (26), and Laguesse (21)). These various authors are, however, not all agreed as to their nature. Langerhans, Saviotti, Latschenberger, and Laguesse, who studied them from the embryological point of view, believe them to be epithelial in character. Pflüger thinks they are multipolar nerve cells; of the others, each has an interpretation of his own.

These cells are not numerous in the hedgehog, but can be readily recognised near the mouths of the acini by their elongated, brightly staining, almost diaphanous nuclei, as pointed out by Laguesse. They lie in the lumen itself, covering over the secreting cells, but not forming a definite wall for the tube; by their staining reactions they are evidently epithelial in nature. Beyond these the channels are very narrow, and lined by the secreting cells; they have no walls other than the envelopes of the cells. When the cells are resting and full of granules this lumen is almost invisible, but becomes readily recognisable when the cells have shrunk, owing to the disappearance of the zymogen granules. The canals of Langerhans are then seen to radiate from the central channel, but do not extend beyond the level of the outer zones of the cells. Owing to a certain amount of precipitated secretion in the tubules produced by the corrosive, the extent of these fine channels can be readily seen, for, inasmuch as this precipitated material is readily stainable, like the zymogen granules, of an intense black by Heidenhain's iron alum hæmatoxylin method, they appear mapped out in sharp black lines, and it will be readily seen that they extend no further outwards than the inner limit of the non-granular zone of the cells, beyond which the much less deeply-stained cell envelopes are visible; for, whilst the cells

adhere together by their outer zones, their inner zones are free, and after secretion these separate somewhat, leaving the channels called after Langerhans.

We also know from the researches of Klein (19) that thin-walled lymphatics lie in the connective tissue immediately outside the secreting cells, and I believe the pericellular canals described by various authors (Turner (42), Giannuzzi (9), Saviozzi (40), and Arnozan and Vaillard (1)), after injection, to be due to the injection forcing its way beyond the canals of Langerhans between the cells into them. The last-named investigators state clearly that the little blue frames seen by them surrounding the cells are due to over-injection, separating the cells from one another and from the subjacent tissues.

Connective Tissue.—The amount of connective tissue in the pancreas of the hedgehog is very small, and is reduced to a mere vestige between the acini; it is everywhere of the usual fibrous type, with connective-tissue corpuscles at intervals. There are also a few lymph corpuscles in it (Heidenhain (12), Lavdowsky (28), Klein (19), Henle (14), and others), but at present I have seen no coarsely granular corpuscles, which is rather surprising, since in a former communication I have described their great abundance in other connective tissues during hibernation, notably in the tongue and œsophagus (4).

The lymphatics are very numerous, each acinus having one or more at its periphery; the large blood-vessels and ducts also have lymphatic trunks twining between and around them (Klein (19)). Many of these during hibernation are in a state of engorgement.

The ganglion cells situated in the fibrous tissue surrounding the larger vessels are numerous, and usually of large size. They are uninucleated, and present all stages of fatigue; many, however, are in the resting condition. They are especially interesting in presenting with great distinctness the "canals" of Nansen (32), several often occurring in one cell. Each canal has running up its centre a piece of tissue directly continuous with the cell envelope, and therefore confirms the view put forth by G. Mann (30) that these channels are not true canals, but are produced by invaginations of the cell envelope into the protoplasm. The Pacinian corpuscles described in the case of the

dog and cat by Harris (10) are also fairly numerous in the hedgehog, near the head of the pancreas.

Finally, the islands of Langerhans (Heidenhain (12), Saviotti (40), Kölliker, Kühne, and Lea (20), Renant (39), Podwysotszki (38), Henneage Gibbes (15), Lewaschew (29), Arnozan and Vaillard (1), and Laguesse (23)) are numerous, though small, and contain many large cells, filled with fine eosinophilous granules.

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AN ACCESSORY SEGMENT IN THE PULMONARY VALVE. By KEITH CAMPBELL, M.B. (Edin.), *Assistant Medical Officer, Perth District Asylum, and formerly Demonstrator of Anatomy, University of Edinburgh.*

THE post-mortem examination was held on a man (J. C.) who had been a patient in the Perth District Asylum, Murthly, under the care of Dr G. M. Robertson, for four years. He suffered from chronic chorea, with mental enfeeblement, and died from extensive gangrene of the lung.

During life nothing abnormal was observed in the cardiac area of the chest, and there was no history of rheumatism.

Heart.—In the interval between the right anterior and the posterior segment of the pulmonary valve, a fourth segment was found, similar to the others in shape, but much smaller.

The depth of this segment was about one-third the depth of

the others, from the free to the attached edge; the maximum breadth of the segment being one-fifth the breadth of the others.

Towards the attached border a certain amount of fibrous tissue was interposed between the two layers of endocardium, but for one-third of its total depth towards the free edge the two layers of endocardium were in apposition, with practically no fibrous tissue between them. There was no corpus Arantii.

Laterally, at the upper part, the segment was attached to the adjacent segments. From the free concave border two delicate cords arose, the one on the right side springing close to the right extremity of the segment, and going to be attached along with the posterior extremity of the right anterior segment. The other, which was larger, arose near the centre of the free edge of the segment, and was attached along with the right extremity of the posterior segment.

Both of these cords were quite free and distinct. They consisted of some fine strands of fibrous tissue, continuous, on the one hand, with the fibrous tissue near the attached border of the segment, and on the other with the wall of the pulmonary artery. These strands were covered by the smooth lining of the endocardium.

The space between the wall of the pulmonary artery and the segment was found to communicate rather freely with the sinus behind the posterior valve segment, and to a less extent with the sinus behind the right anterior valve segment.

The posterior segment was appreciably smaller than the two anterior ones.

The pulmonary valve was competent.

The aortic valve was normal. There was no hypertrophy of the heart, and no other abnormalities could be detected.

There were no signs of endocarditis or endarteritis in the heart and large vessels.

STUDIES IN THE PERITONEUM: ITS ARRANGEMENT
IN ANIMALS. By BYRON ROBINSON, B.S., M.D., *Professor
in the Post-Graduate School, Chicago.*

THE peritoneum has been singularly neglected so far as regards systematic publications. As the lines of my work have been cast in the fields of abdominal surgery, I have naturally been led to study the peritoneum and viscera. For eight years I have been slowly collecting data for a systematic and illustrated work on the peritoneum. But one soon finds that any work on the peritoneum, to be of any value, must be based on comparative labours. So I have carefully examined many of the lower animals and fetuses, to observe the evolutionary steps of peritoneal development along the ascending scale of mammalian life.

Every species of animal presents peculiar features in the peritoneum. The amount of peritoneum possessed by an animal depends much on its mode of nourishment and living. Coarse food, which requires long tarrying in the digestive canal, demands a long gut and much peritoneum to cover it. The giraffe, which lives on leaves and woody fibres, is reported to have a digestive tube 250 feet long. I have noted some 80 feet of digestive tube in the pig. I examined a two-year-old colt, and measured some 85 feet of intestines. One can find about 120 feet of gut in an ox. The dog, I have observed, has some 12 feet of digestive tube. Now, there is a relative amount of peritoneum in any animal according to the length of its digestive canal. The feline carnivora have a short digestive tube, and yet the folds of the peritoneum of the cat are very liberal. It is in the cats that one can find marvellous groundwork for the correct comprehension of the relatives of the peritoneum in man. Especially is the CAT's peritoneum instructive in two points, viz. :—

(a) It shows beautifully the development of the mesogaster, and that about the stage of man's embryo at the end of the second month. It shows that the great omentum or mesogaster

arises from the mid-dorsal line, and inserts itself into the greater curvature of the stomach. The great omentum of the cat shows plainly and distinctly that the lesser omental cavity is merely a depression in the right wall of the mesogaster, that the depression in the right wall of the mesogaster has simply increased into a great bag (lesser omental cavity), until its circumference has gradually contracted into a neck—Winslow's foramen. Winslow's foramen is simply a narrow neck leading into the wide depression in the right wall of the mesogaster. If one lifts a cat's stomach well up and pushes it to the right, he can observe the mesogaster arising from the vertebral column. The great omentum in a cat reaches well into the pelvic cavity. This great omentum is not to keep its intestines warm. It does facilitate motion. It is not a storehouse for fat. It does prevent infectious invasions. It is the cat's peritoneal protector against infectious invasion. It prevents adhesions of the gut to the anterior abdominal wall. The development of the great omentum appears to be due to the enlarged liver forcing the stomach down, the rotation and twisting of the stomach and the development of the diaphragm, aided by the peculiar relation of the spleen and pancreas. Also must be added in the higher mammals the transverse colonic relations to the great omentum. But the transverse colon plays no rôle in the development of the cat's omentum, as the omentum and transverse colon do not have any especial relations in the cat.

(b) The second very instructive character in a cat's peritoneum is the slight mesenteric rotation which exists in the carnivora. The great intestinal loop has only just begun to rotate, say one quarter of a turn or less. The cæcum is still in an adult cat at a level with the umbilicus. The cæcum has just begun in a most distinct manner to steal away the anterior or left blade of the meso-duodenum and appropriate it to cover the growing lower end of the right colon, or what is such in man. In fact, the rotation of the great intestinal loop has proceeded so slightly in a cat that it might be said that a cat possessed a common mesentery (mesenterium commune). The flukes or sacs of peritoneum projecting from the sides of the bladder are characteristic of carnivora and some fish which I have examined. They are like omenta or appendicæ. It is noticeable that those flukes are

most prominent in relation with the genito-urinary organs, *i.e.*, they have an original relation with the Wolffian bodies. The Wolffian bodies were originally large, and left remnants of peritoneal folds, which were supplied richly with blood. A valuable knowledge of peritoneal structure and function can be obtained by examining lower animals. It shows well the evolutionary steps in the development of the peritoneum. It is wonderful in structure in regard to the gastro-hepatic omentum, great omentum and gastro-splenic omentum. It is difficult to understand why the omenta are so liberal in size.

The Arrangement of the Peritoneum in Man and Animals.

The peritoneum is a cavity lined by endothelium, and in connection with the lymphatic system. The lymph spaces are often divided by bands or septa, and the partitions are covered by endothelium. The lymphatic system presents a great variety of tissue forms: the great lymphatic may be simply a free tube, trabecular, structure many-chambered, or large open spaces. The peritoneum is a lymph cavity, having no partitions or separate chambers. It is claimed that the formation of distinct lymph spaces is due to the pressure of fluids. It has long been pointed out by old writers that spaces lined by endothelium similar to the peritoneal cavity existed in connection with the lymphatic system. It is remarked by Anderson that lymphatics are abundant where tissue movement is active. When opportunity offers for active interstitial motion, lymph spaces arise. In short, motion and lymph cavities are inseparable. Now, it may be observed that certain parts, *e.g.* viscera, are active, while the surrounding parts (walls) act entirely independently, so that it may be stated that the activity of the distinct parts and the independence of surrounding parts are associated with large lymph cavities. Hence, pressure of fluid and active motion of one part on adjacent parts are the two conditions of these spaces. The pleuro-peritoneal and arachnoid cavities are doubtless the result of the independent action of the viscera on the containing walls, aided by fluid pressure. Of course, all motion between walls and viscera must be considered as relative.

Anderson quotes Milne-Edwards to the effect that invertebrate animals with peri-visceral spaces have incomplete peritoneal coverings, and never mesenteries like vertebrates. Generally, the parietal peritoneal layer is imperfect, and the sac is more or less open. The peri-visceral spaces communicate with the outside world by pores. A general view of the condition of these peri-visceral spaces in their gradual disappearances would indicate that the independent action of the body-walls sets the digestive tube free. It may be noticed that, as the peri-visceral space gradually diminishes, it is replaced by sinews or muscle. The peritoneal cavity is a great lymphatic sac intersected by no band trabeculae or chambers. Its spacious cavity is due to the coalescence of innumerable small lymph chambers, and also to the independent action of its adjacent walls.

A good illustration of the pressure of fluids in adjacent chambers causing atrophy and final disappearance of the intervening walls, may be observed in a multilocular ovarian tumour. In fact, I have often observed in such tumours the actual progress of the disappearance of the septa. The tissue or septum first begins to atrophy and to disappear at its middle point, or at the point which exists the most distant from the circulation. This atrophying process, from the fluid pressure, progresses until chambers arise which contain quarts of fluid. Fluid pressure on intercellular spaces, with independent movement of adjacent structures, accounts for large chambers in multilocular ovarian tumours; and the same principles apply to the coalescence of lymph spaces, which result in the production of serous cavities, to which belongs the peritoneum. Motion, active or relative, is always connected with abundant lymph spaces and serous cavities. The bursae found about tendons are a good example of motion calling up serous cavities. Independent action of walls or adjacent tissue sooner or later enables the coalesced lymphatic spaces to be detached. In certain fish the intestine shows remnants of the bands stretching through lymphatic spaces, as the digestive tube is still, in adult fish life, held in position by irregular bands, which not only serve for support but transmit vessels and nerves. I have noticed in examining fish that all the digestive tract was not entirely free in the peritoneal cavity, but held in position by connective tissue.

Milne-Edwards is quoted as asserting that in most amphibia and reptiles, muscle bands extend into the mesentery along the blood-vessels. Owen states that the mesentery of the marsupials is simple, like that of reptiles. Cleland announces that in the wombat the duodenum passes behind the transverse colon as it does in the human, and that there is a common mesentery to the small intestines and the ascending colon and cæcum. The wombat resembles man, however, in possessing an appendix, and also in embryo. Cleland's drawing of the wombat's abdominal viscera represents an earlier stage of man's digestive tract, as the right half of the transverse colon, the descending colon, the cæcum, and all the small intestines except the duodenum, have a common mesentery. At the third foetal month one may find in the human embryo just the relations found in the adult wombat.

In cetacea it is asserted that the intestine is suspended by a common continuous mesentery. In the porpoise, says Hunter, "the duodenum does not pass behind the mesentery, as in most animals of that class." Anderson notes that in a specimen of *Phocæna melas* which he examined, the stomach was connected to the liver by the gastro-hepatic omentum. The great omentum contained an omental cavity, but had no connection with the large sac. The foramen of Winslow was absent. In the badger and dog,—the last-named animal I have repeatedly examined,—the arrangement of the peritoneum represents a certain stage of embryonic man. In them the stomach has its three omenta like man; however, not so complicated. The right half of the pancreas lies in the meso-duodenum, while the left half derives its coverings from both omental sacs. The great omentum is very abundant, and will stretch far beyond the pelvis when unfolded. It is fixed to the median line between the kidneys, for a dog has no transverse colon like a man. The duodenum is some 12 inches long, and has an extensive meso-duodenum of 6 inches from the vertebral column to the gut (dog 25 lbs.). The lower end of the duodenum is at the right side of the attachment of the great omentum. The same point holds good in man in early embryonic life, as the great omentum forms its connection in him to the transverse colon from right to left. But the adult dog has only evolved to man's embryo of the third

month. Fusing of the lower end of the dog's duodenum with the lower right border of the great omentum exists for about an inch. It has just arrived at the third foetal month of man. Below the duodenum in dogs, the gut forms a large loop, with its neck attached to the posterior abdominal wall. In this loop runs the superior mesenteric artery. The neck is only the width of the two bowels composing it. The lower end of the loop ends in the straight, large bowel which runs into the pelvis and ends at the rectum. A dog's large bowel has no *tænia coli*, no *sacculations*, and, so far as I have noted, no *appendicæ epiploicæ*. In the dog the great omentum is attached by one end to the great curvature of the stomach, and the other inserts itself into the median line of the posterior abdominal wall. The pancreas lies in the folds of the gastro-cœlic omentum. The ascending layer of the great omentum, derived from the sac itself, passes up and emerges into the anterior layer of the transverse colon. In the dog, it seems to me that the views of Meckel, Haller, and Müller as regards the formation of the transverse meso-colon could be refuted. It appears to the author that the dog's omentum and transverse colon show distinctly that the transverse colonic mesentery is not formed by fusion, coalescence, or absorption, but by readjustment. The peritoneum is rearranged so that the colon transversum appropriates from the great omentum sufficient to form its meso-colon. It would appear that in the dog the relation of the so-called transverse colon and the great omentum would indicate that rearrangement, readjustment and appropriation of peritoneum, through hypertrophy, atrophy and positional changes of viscera, explain matters, rather than coalescence and atrophy. This view arose in my mind from the examination of dogs and embryos of man and animals. In the dog the cæcum, with no appendix, is situated high, and just to the right of the median line. The cæcum and lower end of the duodenum is fused for about an inch by inter-cellular tissue, but held in place by peritoneum. The dog has no costo-colic ligament (*ligamentum phrenico-colicum sinistrum*), nor no sigmoid flexure. The proportion of his bowel (for a 25 lb. dog) are—duodenum 1 foot, small intestines 8 feet, and large intestine 1 foot. The foramen of Winslow is represented by a slit dorsad to the portal vein. The foramen will admit two fingers, which

pass into a capacious sac (lesser omental cavity) situated behind the stomach. The great omentum is very thin, and penetrated by large numbers of small, fine holes, much fenestrated.

The kidney is almost entirely surrounded by peritoneum, which in some cases presents almost a meso-nephron. The dog has projecting into his peritoneal cavity, pouches of peritoneum filled with fat, resembling appendicæ epiploicæ. I have measured two of such projections in one dog, and find that they measured 3×1 inch. Such accumulations of fat are found in exactly similar localities in man, *i.e.*, around the hernia orifices and along the bladder. Besides, a peculiar fold of peritoneum exists on each side of a dog's (male) bladder, resembling the broad ligaments of women. I have frequently found a similar fold passing transversely across the top of a man's bladder.

The great omentum in the ferret (*Mustela furo*), pole-cat (*Putorius fætidus*), badger (*Meles taxidea*), otter (*Lutra vulgaris*), is arranged similarly. In farinaceous Europeans, the intestinal canal is connected to the posterior abdominal wall by a continuous mesentery. The great omentum is not connected to the colon. In quadrumana the great omentum is attached to the right end of, or to all the transverse colon. The omentum may adhere only to the right end of the colon, as in *Cynocephalus anubis*, or to the right third, as in *Cebus capucinus*; but in the last case some of the ascending colon receives a share. Among the lemurs, *Galago crassicaudata* has a great omentum which is large, and confined to the left side. The elongated transverse colon consists of an ascending and descending limb—a kind of V-shaped tube found in abnormal man, or the normal tube found in the horse. In typical man, apparently the highest or last most complicated peritoneal structure, the colon transversum, lies between the layers of the great omentum. The duodenum passes behind the meso-colon transversum. The pancreas, unlike that of animals, lies behind the great omentum (not between its layers), and also behind the lesser omental cavity.

In fish, meso-colon and mesentery are found undeveloped, as well as an occasional elongated mesentery. In amphibiæ and reptiles more complete arrangements of the peritoneum arise. In birds is found a well-marked duodenum. In lower mammals,

as Hunter pointed out in the porpoise, a digestive tube swings by a simple meso-gastrium. The peritoneal and bowel arrangements become more complex in the dog, which presents an ascending high cæcum, and a partial rotation of the great navel loop—a long evolutionary step; and we find in some of the lower quadrumana that the great omentum begins to attach itself to the right end of the colon transversum; and finally, in the higher classes of mammals, the great omentum is attached to the whole length of the transverse colon. It is a significant and profound fact that man passes through all these noted stages while in embryo. All the changes, and all the evolutionary steps from the lower animals, with a straight digestive tube swung from the dorsum by a simple double membrane—the mesentery—up to the most complicated—man—are comparatively easy, except two, viz., one is the development of the great omentum, and the other is the lesser omental sac as finally found in man. I have left out of the above two questions why the digestive tube rotates from left to right.

It may be noted that the position of the duodenum is due to the atrophying liver. Now, may not the rotation of the digestive tract be due to the same cause, *i.e.*, the rapid shrinkage of an embryonic organ of enormous dimensions. The hepato-duodenal ligament may aid. Also the hepato-colic ligament assists in some cases.

Dr R. J. Anderson suggests that the formation of the small omentum is due to friction. Here, again, would come in the power that interstitial fluid pressure has in making many chambers into a few, and it is aided by the independent action of the body-walls. Dr Anderson concludes that the lesser sac (*cavum omentum minus*) arises independently, and not from the larger sac (*cavum omentum majus*); also that the foramen of Winslow is due to the separation of the meso-gastrium. It seems to the author that the *cavum omentum minus* is plainly a depression in the right wall of the mesogaster posterior, and that Winslow's foramen is but the neck of that depression.

1. In the Pig the general arrangement of the peritoneum does not vary to any great extent in animals. The chief variation which I have noted is almost entirely in the great omentum. I examined the pig embryo in various stages, and found very

little great omentum. The spleen was attached almost along the entire curvature of the stomach, even to a slight distance to the right of the vertebral column. It was in close contact with the stomach, from near the pylorus around the greater curvature of the stomach. The pancreas reached entirely across the abdomen, and lay in the great omentum. Its head reached into the concavity of the duodenum. The duodenal mesentery is very long. The pig has no sigmoid loop, and its descending colon passes along the mid-dorsal line. The meso-colon is not displaced by the growing kidney, as it is in man. The pig has a liberal peritoneum, for his intestines are about 70 feet long. The small intestines in the embryos had a long mesentery. The great bowel loop rotates just as man's does, but in no pig foetus could I find a costo-colic ligament (ligamentum phrenico-colicum sinistrum). The developing kidney in man allows this ligament to be formed. A pig's intestines are an advanced evolutionary step over a dog's, as the cæcum has passed much further in its travels in a pig than in a dog. In a pig the cæcum has passed over in front of the duodenum, and begun to descend toward the right iliac fossa. Though the cæcum has accomplished much more distance in bowel-loop rotation than in a dog, yet it does not lie very much below that of a dog's. The liver is perhaps relatively greater in an embryo pig than in an embryo man. A pig has relatively more peritoneum than a man. His peritoneum is not subject to such fatal peritonitis as man's. The relation of the transverse colon to the great omentum in a pig is similar to that in a dog. The lower layer of the great omentum and the upper layer of the transverse meso-colon join on the backbone just below the pancreas—*i.e.*, those two layers have not coalesced, or rather become readjusted. The stage of a pig's great omentum resembles a human's at about two months. It seems to me that it is plain in a pig's embryo that the liver is responsible for (*a*) the rotation of the stomach, (*b*) for the twisting of the stomach, (*c*) for the descension of the stomach. A pig has an extra large pouch on its stomach on the cardiac end. There exists a large, long single mesenteric gland for the small intestines. In the foetal pig the colon coils around the packet of small intestines. The foramen of Winslow is quite large in foetal pigs.

Dr Lucy Waite and I carefully examined the RABBIT, for the purpose of comparison, with the peritoneum of other animals. The first feature of note in a rabbit's peritoneum is the enormous cæcum, which lies transversely across the abdomen, generally in two double coils. This coiled cæcum almost covers the other viscera as one removes the anterior abdominal wall. In one rabbit the cæcum measured 20 inches, and in another, which we also noted, the cæcum measured 15 inches. The cæcum is a complicated structure, and has many complicated folds of peritoneum surrounding and supporting it, with also an extensive mesentery. Just where the ileum enters the ascending colon, the colon swells into a dome-like structure. At this point the colon is very large. The cæcum contracts irregularly to its blunt end. For the last 3 inches the cæcum tapers very uniformly, and almost retaining the same diameter. The cæcum is sacculated, and has *tænia coli*. The cæcum must represent some ancestral secondary herbivoral stomach. The rabbit has no appendix vermiformis cæci, but it has a structure which closely resembles it. The cæcum of the rabbit is enormously large in proportion to the small intestines. The descending colon is held to the mid-dorsal by a 2-inch mesentery. It is 8 inches long. The splenic flexure shows distinct bands connecting it to the spleen, which lies close to the left curvature of the stomach. The flexura coli lienalis is a right angle. There is no costo-colic ligament. The transverse colon passes across the abdomen in a very peculiar manner. It pursues a course parallel to the long, free duodenum. It lies on the mesoduodenum, almost in contact with the duodenum; and as the duodenum is from 12 to 16 inches long, the transverse colon follows it all the way around, and finally crosses the duodenum at its transverse portion or lower end. No bands or sacs are found on the descending and transverse colons, but sacculi and *tænia coli* begin on the ascending colon, and become very prominent as they approach the cæcum. The duodenum is 12 inches long, its mesentery is $1\frac{1}{2}$ inches, and it contains the pancreas in its folds. The small intestines are 5 feet long. The mesentery is 6 inches. The large intestine is 3 feet 6 inches. The cæcum is 20 inches. Now, the great omentum resembles that of a pig. The greater curvature of the stomach is

well forward in the abdomen. The great omentum is a double fold, is nearly 3 inches long, but it is rolled up, and lies along the great stomach curvature. It does not connect itself to the colon as a double layer or fold, but the fold which lies on the lower side passes to the colon. This single omental blade begins to pass first to the right end of the transverse colon exactly as it may be typically observed in the human foetus and dog. The pancreas lies in the folds of the great omentum. The rabbit is a good sample to illustrate that the lower left border of the great omentum will finally form the phrenico-colic ligament. The fossa duodeno-jejunalis is present. The root of the mesentery is very short— $1\frac{1}{2}$ inches long. The rotation of the great intestinal loop of a rabbit represents that of the human foetus of about four months. The rabbit is more advanced in intestinal rotation than the dog or pig, but it retains the ancestral relic of a secondary herbivorous stomach to a remarkable degree. In the rabbit, as in all mammalia, the peculiar feature in regard to the peritoneum consists in the great omentum, and its connections especially with the transverse colon. It appears to me that the coalescence theory of Haller, Meckel, and Müller is easily disposed in the rabbit's peritoneum. In the place of this theory I advocate that of readjustment or displacement. The part of the peritoneum which lies between the stomach and colon is dragged out, displaced, or readjusted, so that adult relations finally come about. The rabbit's lesser omentum shows well the three divisions which I have previously described, *i.e.*, the pars tendineus, pars flaccida, and pars hepato-duodenale. A rabbit's mesenteries and omenta are far more liberal than in man, and one would think that volvulus would be common in such animals, especially of the extraordinarily long and large cæcum. I saw no appendicæ epiploicæ in the rabbit, but in the rabbit's pelvis one can observe flukes of fat covered with peritoneum from 1 to 2 inches long. Similar projections of fat are found in the dog's pelvis along his bladder. The usefulness of these large projections of fat is unknown. The kidneys are imbedded in solid, thick walls of accumulated fat. The rabbit's peritoneum is exceedingly thin, and the membrana mesenterii propria is proportionately spare. The great omentum does not hang down over the cæcum or small intestines, but

lies rolled up in a bundle along the greater curvature of the stomach.

I have examined the peritoneum of scores of dogs, and it is almost identical with that of the cat. The dog is a convenient animal in which to study the peritoneum, and from which to instruct students. In the horse, one can well see the immensity of the peritoneum, especially in veterinary schools, as they use their material fresh. The solipeds resemble very much the rodents in the arrangement of the peritoneum and the large (double) bowel loops. However, the squirrel has two double-barrelled bowel loops in the ascending colon. In the squirrel is seen the most typical sample of a growing bowel appropriating the peritoneum to cover itself. For example, the cæcum journeys on its circuit to the right iliac fossa, it passes over the extensive left face of the meso-duodenum twice, and as it passes it lifts up the thin shining serous endothelium to cover itself and make a meso-colon dextrum. It is a typical sample to show the process of peritoneal adjustment or displacement, as against the views of Haller, Meckel, and Müller. In the rodents the meso-colon descendens (sinistra) inserts itself directly in the mid-dorsal line.

The chief variation seen in the upper scale of animal life, as regards peritoneal arrangements, arises in the relation of the great omentum and transverse colon. In highest mammals the transverse colon has definite relations with the great omentum, but the most manifestly in man, for I have frequently seen the great omentum (Haller's omentum) extend down to the entering ileum in both adult, and especially in embryonic man. Some difference also may arise in the amount of kidney the peritoneum covers. In the dog there is a meso-nephron, while in man I have never observed one. On the amount of rotation of the navel loop in any animal will depend its final peritoneal arrangements. For nearly all fixed peritoneal attachments have occurred from rotation of the navel loop in higher mammals. The lowest mammals often have a common mesentery from diaphragm to diaphragm, *i.e.*, a mesenterium commune. Even in adult man I have found two cases of mesenterium commune for every hundred subjects examined. The gastro-hepatic omentum is strangely similar in all the above-named mammals, *i.e.*, it is

composed of the *pars tendineus* (Robinson), *pars flaccida* (Toldt), and *pars hepato-duodenale*. The meso-colon sinistra is chiefly inserted in the mid-dorsal region in animals below the quadrumana. But in bimana the growing kidneys appropriate the vertical meso-colon dextrum et sinistrum to cover themselves, and also force the colon-sinistrum to the left abdominal wall, and in man there is no vertical meso-colon.

In regard to the arrangements of the mesenteries, these animals with long peritoneal supports must be greatly endangered by volvulus. The solipeds and the rodents are in imminent danger of volvulus, and reliable veterinary surgeons informed me that volvulus is often fatal in the horse. The rodent's enormous cæcum is surely a menace to life by volvulus. Many a time I tried to produce a volvulus in the dog, but the short carnivorous digestive tract, with its relatively short mesentery, prevented permanent volvulus, except it was sutured in position, and even then, many times in my experiments, the sutures were torn out as the volvulus forcibly reduced itself.

Retro-peritoneal hernia might also occur in the lower mammals as well as in man. However, I think retro-peritoneal hernia in the fossa duodeno-jejunalis must be very rare in mammals below the quadrumana. The fossa duodeno-jejunalis depends on the amount of rotation of the navel loop, so that the vena mesenterica inferior may be dragged well toward the portal vein to empty into it, and thus projecting permanently upward a large peritoneal fold. In other words, the fossa duodeno-jejunalis is more prominent in higher life, and hence more liable to engage a bowel loop in the fossa, but Winslow's foramen is more liable to produce hernial strangulation of bowel loops in lower mammals than man, for it is a longer and more exposed slit in mammals than in man. In man, Winslow's foramen is protected by the hepatic flexure of the colon, the liver and right kidney, to a very much greater extent than it is in lower animals.

A CASE OF ECTOPIA VESICÆ, WITH PATENT VITEL-
LINE DUCT. By J. H. SEQUEIRA, M.D., *Demonstrator of*
*Anatomy, London Hospital.*¹

THE subject of this interesting and rare malformation was a female child, born at full-term, who died at the London Hospital four days after birth. The case was under the care of Mr M'Carthy, who has kindly permitted me to describe it.

External Appearances (fig. 1).

The lower part of the abdomen is occupied by a somewhat triangular area of mucous membrane, at the apex of which is

1

Duct.
of Bladder.
ductus.

Duct
from Min.
from May.

Fig 1.

attached the umbilical cord. This mucous area is the open bladder, and at its lower part there is a large funnel-shaped

¹ Communicated to the Anatomical Society, February 1896.

orifice, the patent vitelline duct, leading directly into the lower part of the ileum. On each side of this cavity, which is large enough to admit the forefinger, the bladder wall is pushed forwards as a large rounded eminence. On the right protrusion there are three orifices. The lowest of these, which is slit-like in form, is the opening of the common urogenital duct. The middle orifice is guarded by lip-like folds of mucous membrane. It leads into a short blind tube, which, from its position just in front of the opening of the genital (Müllerian) duct, is probably the duct of Gärtner. The superior orifice also leads into a short blind tube.

On the left side there are two openings upon the bladder wall. The inferior is circular, and leads into the genital (Müllerian) duct. The anterior resembles the middle orifice on the right side, being guarded by mucous folds, and ending blindly. This is probably the left duct of Gärtner.

The labia majora are two transversely placed folds of skin, approaching the mesial plane just in front of the anterior extremity of the gluteal cleft. Two thin folds of mucous membrane lying in front of the labia majora probably represent the labia minora.

In front of these the mucous membrane is smooth, and extends to the lower margin of the large opening of the vitelline duct.

There is no anal dimple.

Internal Appearances (figs. 2 and 3).

The bowel is altogether 1·37 mètres long.

The duodenum presents no abnormality.

In the upper part of the jejunum there is a short—evidently recent—intussusception about 2·5 centimetres long. This invagination probably occurred *in articulo mortis*.

The ileum may be considered in two parts. The upper portion presents no abnormality, and ends by a small orifice in the funnel-shaped vitelline duct. It opens at right angles to the terminal part of the ileum (fig. 2). This part of the bowel is in direct continuity with the vitelline duct, and has a wider lumen than the upper part.

The cæcum is a short blunt protrusion, opposite which the vermiform appendix (fig. 2) arises.

The large bowel, which is 11·2 centimetres long, forms a single loop, and ends blindly in the pelvis opposite the end of the

Fig 2.

coccyx. It is attached to the posterior wall of the abdomen and pelvis by a mesentery, the line of attachment of the rectal portion running from the left sacro-iliac synchondrosis to the coccyx.

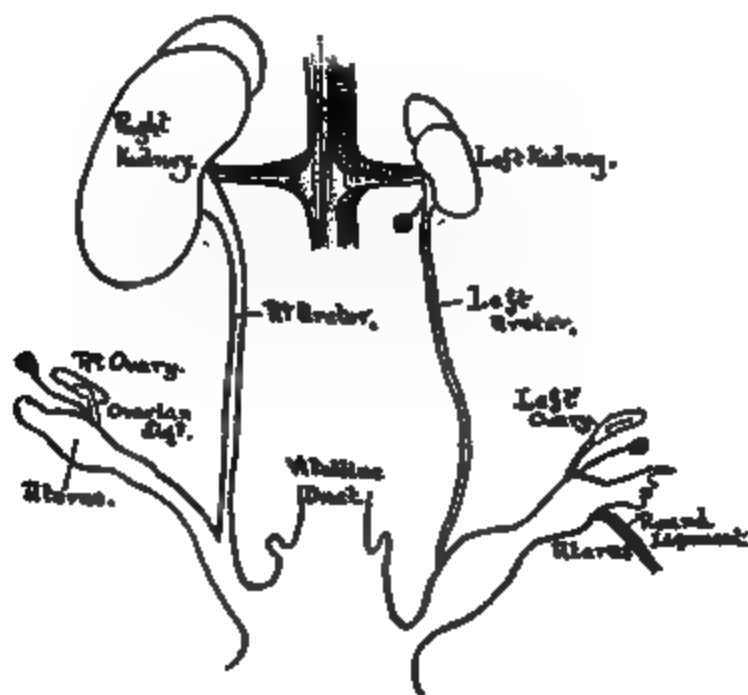


Fig 3.

The kidneys (fig. 3) lie on each side of the spine in the lumbar region.

The right kidney is large. It measures 5 centimetres in its long axis. It is surmounted by a somewhat flattened adrenal body.

The ureter communicates below with the lower end of the genital duct.

The left kidney is atrophic, measuring about 1 centimetre in its long axis. The adrenal is triangular, and is about the same size as the kidney.

The ureter is a fine tube, which, although attached below to the left genital duct, has no communication with it.

Just internal to the left kidney lay a small, rounded, red body. Its structure has been kindly examined for me by Dr Bulloch, who reports that he is of opinion that it is an accessory adrenal body.

The right ovary (fig. 3) is an elongated body, lying close to the outer end of the genital duct, and is attached to it by a band, the ovarian ligament. Microscopically the organ consists of a stroma, and the periphery contains numerous ova, each being surrounded by a layer of fluid, which again is bounded by a capsule with flattened cells.

The lateral part of the genital tube has a well-defined swelling upon it. The wall of this contains unstriped muscular fibre, and represents a rudimentary uterus. The mesial portion of the tube is thinner, and the ureter opens into it at an acute angle. The common urogenital duct thus formed opens on the surface by the slit-like orifice above described (see fig. 1).

The left ovary is similar to the right.

The ovarian ligament is well defined.

The oviduct is much larger and thicker than that of the right side, and forms a well-developed uterus and vagina, opening by a circular orifice at the lower part of the left half of the bladder (fig. 1). A well-marked round ligament runs from this cornu uteri to the inguinal region.

The ureter is attached to the back of the lower part of the genital tube, but has no communication with it.

On each side the hydatid of Morgagni and the parovarium are found in their usual relation to the broad ligament.

The pelvis (fig. 4) is of the form usually found in cases of ectopia vesicæ. The rami of the ischium and pubes are short, and directed somewhat forwards. There is an interval of 4·5 centimetres between the lateral halves of the pelvis in front.

In all other respects the body was normal.

On examining the literature of the subject, I find that no similar case has been recorded in this country. Ahlfeld(1) describes the condition, and gives figures in his *Atlas* of cases of a somewhat similar nature. In one instance, originally described by Rossum, the small intestine, the cæcum and appendix, and the colon, all opened on the surface of an extroverted bladder.

7

Fig 4.

In another case, described by Witner and figured by Ahlfeld, the small and the large intestine opened on the surface of the bladder. In each of these cases the normal anus was absent, and the ureter and genital ducts opened on the ectopia, but by separate orifices.

The conditions found here depend upon defects of development at a very early period of foetal life. The closure of the ventral surface of the embryo begins in the third or fourth week, and the vitelline duct becomes obliterated normally about the sixth week. In this case, as in others of ectopia vesicæ, we have not only to deal with a failure of closure of the bladder, but of the whole body-wall. The abdominal muscles and the pelvic bones are present, but fail to unite.

Attention has naturally been directed to the development of the allantois in the inquiry after an explanation of these malformations. As usually described, the allantois arises as a hollow diverticulum from the hind-gut, which penetrates a mesoblastic stalk (Bauchstiel of His(2)), which is attached to the chorion. The lower part of the allantois becomes the bladder, and into it the ureters and genital ducts open. The possibility of the

bladder being developed by two laterally symmetrical halves has to be considered, for this would explain the failure of union anteriorly. Evidence derived from the study of the allantois in early fetuses negatives this hypothesis. On the other hand, there are a few instances of bifid bladders. Three cases are quoted by Koenig (3). The first is figured by Blasius (4). The bladder is divided by a median partition into two symmetrical halves, into each of which a ureter opens. The two cavities fuse below. A second instance is described by Meckel (5). Here the bladder is prolapsed in two symmetrical halves. A third case, described by Scarenzio as *vesica bifida*, I have been unable to examine. There is also a specimen described by Mackinder (6) which may possibly be a duplicate bladder, but which, I think, is really a bladder with a large diverticulum. It is to be noted here, however, that these cases are not comparable with ectopia vesicæ. The failure of union is at the upper part.

Bartels (7) was the first to point out that the fault may lie in some abnormal condition of the alimentary canal; and the specimen now described, together with the somewhat similar cases cited by Ahlfeld (1), supports the view that the vitelline duct might be the obstruction which prevents the coalescence of the lateral halves. Against this view it is only necessary to state that cases in which a patent vitelline duct coexists with ectopia are of extreme rarity.

Ahlfeld (1) is of the opinion that the rupture of an over-distended allantois may be the cause of ectopia. But this, while accounting for the open condition of the bladder, does not explain the opening of the vitelline duct upon its surface, nor do I see how it explains the fission of the anterior abdominal wall and pelvis.

Shattock (8) gives a far more probable hypothesis. He thinks that the primitive cloacal invagination, the proctodæum, which normally opens up the lower end of the rectum and the lower end of the urogenital sinus, by an undue extension forwards and upwards, lays open the anterior wall of the urogenital sinus and bladder. There would thus be a complete fission of the parts in the middle line as high as the umbilicus. He points out, with justice, that the minor degrees of this fissure cause epispadias, while further extension produces epispadias *plus* ectopia. Fur-

ther, he calls attention to the fact that ectopia is never found without epispadias. This hypothesis accounts also for the separation of the pelvic bones in front, and of the muscles of the anterior abdominal wall.

If, as in the present case, the vitelline duct opens at the umbilicus, it would, of necessity, be involved in this forward extension of the proctodæum.

One other point of interest is that the orifice of a patent Meckel's diverticulum is often found below the umbilicus (9).

The exclusion of the rectum from the proctodæal invagination in this case is comparable with the well-recognised variety of "imperforate anus," in which the rectum ends blindly, and there is no anal dimple. The separation of the rectum from the urogenital sinus has taken place in the usual way, but the anal portion of the proctodæum is not separated off.

In conclusion, I must acknowledge my indebtedness to Dr Bulloch, who undertook the microscopical examination of the organs for me, and to Mr H. Balean who has made the drawings.

The specimen will be placed in the Museum of the London Hospital Medical College.

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SOME STRUCTURES IN THE ELBOW-JOINT. By EDRED.
M. CORNER, B.A., B.Sc., Scholar of Sidney College, Cambridge.¹

BEFORE describing certain structures in the soft parts of the elbow to which I wish to call attention, it is necessary to refer very briefly to the condition of the bones in certain different types of elbow-joint. In the horse the radius articulates with the whole breadth of the humerus, while the ulna forms a small back wall to the joint. Variations of the horse-type of elbow-joint consist mainly in the amount of the ulnar projection below the humerus. In the dog's elbow the radius does not monopolise the whole of the breadth of the distal articular surface of the humerus, because a process of the ulna has appeared on the internal side of the head of the radius, which articulates with the lower end of the humerus. Such a joint is capable of slight pronation and supination.

In the elbow of the Felidæ pronation and supination can take place to some extent. The area of articulation of the radius with the humerus is larger than that of the ulna in about the ratio of 2:1. The strain on the ulna will be greater in digitigrade animals than in plantigrade animals; hence it is usual to find more or less complete fusion of the bones of the forearm of the former, while in the latter the bones are usually separate. The apparent exceptions to this general rule are typified among the Carnivora. In the Felidæ, for example, a certain amount of pronation and supination can take place, and for this the radius and ulna must be separate. A similar reason accounts for the apparent exception shown by the Canidæ, in whom the movements of pronation and supination are very slight.

I have examined the soft parts of two groups of elbow: firstly, that of man, in which pronation and supination is possible; and secondly, those of the ox and sheep, in which such movements are impossible. The joints of the cat and dog were dissected as intermediate types. Two joints of each of the last four animals were dissected, and ten joints of man. The following descrip-

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tions of the joints of these several animals deal only with the special points to which I desire to direct attention.

When the elbow of the ox was sawn sagittally across from the back to the front, rather internally to the middle line, a strong ligament was seen to project somewhat into the joint from the outer and posterior part of the capsule. On the posterior and external side of the trochlea there is a sharp ridge, external to which is a rough surface from which the ligament arises apparently by two heads, the fibres of which unite. The origin is long, and is directed downwards towards the elbow-joint. The ligament is inserted on the base of a rough triangular surface on the ulna, between the articular surface of the olecranon and the external articular surface which participates in the elbow-joint. The base of this triangular surface is external.

Cooper's ligament is present as an exceedingly strong band, consisting of about four large bundles of fibres. It arises from the internal side of the olecranon. The two most external strands are inserted into the radius; the third, and by far the largest, into the internal lateral ligament. The last and smallest strand is lost in the capsule of the joint.

A strong ligament on the outside of the joint, corresponding to Cooper's ligament on the inside, arises from the posterior border of the external articular surface of the ulna, and is inserted into the external lateral ligament. It is partially covered by a tough fat-holding membrane.

On the inner side of the external lateral ligament is a long semilunar fold of fibrous tissue, which projects between the outer parts of the bones forming the humero-radial joint. It is more or less continuous with the fibrous tissue on the external ligament described above, but is not fatty.

The sheep's elbow was sawn across similarly to that of the ox. The tendon of the anconeus was visible within the joint in its outer half, between the external lateral ligament and the ligamentous fold on the postero-external aspect of the joint. The last named ligament has a broad origin from the outside of the ridge external to the trochlea behind, and a rough ridge extending downwards towards the external condyle. The fibres from this wide origin (10 to 12 mm.) approach each other, so that the ligament is narrowest at its middle, from which point the fibres

separate again in another plane. Its posterior fibres are inserted into the anterior edge of a rough surface on the outer side of the olecranon; and the rest along a line directed from this point towards the centre of the articular surface of the olecranon; the whole of the insertion being 15 mm. long. The cause of this peculiar shape of the ligament, and its distance from the elbow-joint, is probably due to the passage of the anconeus between it and the external lateral ligament.

FIG. 1.—Elbow of Sheep.

Cooper's ligament is represented by two strong bands of fibrous tissue attached to the inner surface of the olecranon and to the internal lateral ligament.

The external ligament, corresponding to Cooper's ligament, has a similar course. It is situated just above the superior external radio-ulnar articulation. There is no line of separation between it and the fibres of the superior external radio-ulnar ligament. On the internal side of the external lateral ligament is a semi-lunar fold, as in the ox.

In the dog's elbow-joint a broad and strong ligament on the postero-external aspect of the joint arises from the outer surface of a sharp ridge on the outer side of the trochlea for some distance. It consists of two parts, the anterior being the stronger, its fibres running a little more obliquely backwards than those of the posterior part. It is inserted into the outer side of the articular surface of the olecranon.

Cooper's ligament is represented by a single strand, connecting the olecranon with the internal lateral ligament.

The external ligament, corresponding to Cooper's ligament, is represented by the upper fibres of the superior external radio-ulnar ligament.

FIG. 2.—Elbow of Dog.

A semilunar fold is present on the inner side of the external lateral ligament, and projects as a lip between the radius and humerus.

The cat's elbow possesses the power of pronation and supination. The projecting fold on the postero-external aspect of the joint is well developed, and arises from the angle where the sharp external trochlear ridge joins the rough condylar ridge. It is inserted on the posterior superior angle of the superior radial facet on the ulna and the edge of the ulna immediately above this. A posterior portion, corresponding to the posterior part of the dog's, is present, but is less easily distinguished from the capsule. Cooper's ligament is thin and small.

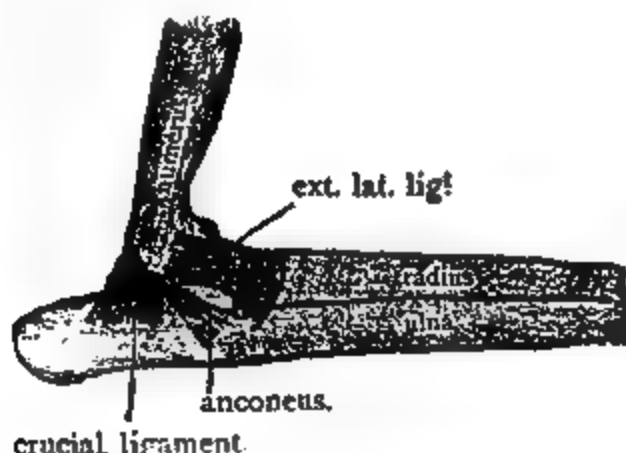


FIG. 3.—Elbow of Cat.

The external lateral ligament, corresponding to Cooper's ligament, is represented by the superior fibres of the orbicular ligament.

The semilunar fold on the inner side of the external lateral ligament is present as in the other quadrupeds.

On the outer side of the human trochlear surface, and on the back of the humerus, is a distinct ridge, which divides into two at its lower end, a blunt ridge between the trochlea and capitellum and a sharp ridge forming the posterior boundary of the capitellum.

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FIG. 4.—Human Elbow, coronal section. Internal lateral ligament cut and humerus thrown back.

A fold arises from the point of bifurcation of the ridge, which runs downwards and forwards to be attached to the blunt superior posterior angle of the upper radial facet on the ulna. This fold was present in all the elbows examined, and in one a second fold was present on the inner side of the main fold.

It is unnecessary to describe Cooper's ligament, since it is in the text-books.

The external transverse ligament is represented, as in the cat, by the superior fibres of the orbicular ligament.

A semilunar lip was present on the inner side of the external lateral ligament in all the elbows examined. Its size was more variable than that of the ligament on the postero-external aspect of the joint.

Besides this semilunar fold there are other folds, some of which are not well marked.

1. On the inner side of the lower part of the postero-external ligament is a fold extending between the radius and humerus, in front of the ligament between the humerus and ulna; this sends a process down into the superior radio-ulnar joint, the inferior fold.

cruciate

internal fold

FIG. 5.—Human Elbow, sagittal section through ulna and humerus. The bones are pulled apart and show head of radius in joint.

2. The Haversian glands fill the rough depressions on either side of the base of the articular surface of the olecranon. The internal one is connected with a small semilunar fold on the inner side of the internal lateral ligament, which projects slightly between the ulna and the humerus.

These processes are represented in the joints of the lower animals, but are less well defined, and not so fatty.

The postero-external fold consists of a reflection of synovial membrane with some fibrous tissue inside. Both it and the transverse fold at its base were present in the section of an elbow of a three months foetus, as were also the two folds homologous to the fibro-cartilages of the knee.

The fold of the capsule, which I have described as present in these types of elbow-joint, in all cases, arises from the extensor surface of the humerus. In this particular it suggests homology with the crucial ligaments of the knee. The latter are attached to the tibia, the former to the ulna. In the knee the fibula does not articulate with the femur, while in the elbow the ulna articulates with the humerus. Hence the humero-ulnar joint has no homologue in the knee. But as the fibular-homologue, the

ulna, is situated in front of the joint, *i.e.*, the extensor side, it replaces the homologue of the tibial spine and crest, and so the insertions of the crucial ligaments are shifted from the hypothetical homologue of the tibial spine and crest to the ulna. In the ox the crucial fold is large. In the sheep it is strong, but is divorced from the joint, and altered in its shape by the anconeus passing between it and the stronger external lateral ligament. In the dog the ligament is broad, its most anterior fibres checking over-extension, its most posterior fibres over-flexion. In this case, therefore, there is analogy as well as homology to the crucial ligaments of the knee. In the cat a similar state of things exists, but the joint approximates more to the human type, in which the fold is long and narrow, and, if strong enough, could prevent over-flexion. It is therefore analogous to the posterior crucial ligament.

In the ox both lateral ligaments are inserted into the radius, and we have Cooper's ligament and the external ligament corresponding to it present and well developed, binding the upper portion of the ulna to the radius.

In the sheep's elbow, Cooper's ligament and the external ligament corresponding to it are fairly well developed, and the latter has become continuous with the fibres of the outer ligaments of the superior radio-ulnar articulation.

In the dog, Cooper's ligament is smaller, and in the cat it is smaller still. In the latter animal, as in man, there is a well-developed orbicular ligament, the superior fibres of which represent the external ligament corresponding to Cooper's ligament.

In all the joints examined there was, on the inner side of the external lateral ligament, a semilunar fold which projected between the humerus and the radius; this is probably the homologue of the internal fibro-cartilage of the knee. A homologue to the outer fibro-cartilage of the knee exists in the lip of synovial membrane on the inner side of the crucial fold which projects into the humero-radial joint.

In some joints a similar fold projects on the inner side of the internal lateral ligament. This is not represented in the leg.

The articular surfaces of the lower end of the humerus are developed from two centres of ossification, which are very unequal in size. The centre for the capitellum extends over the blunt ridge separating it from the trochlea as far as the bottom of the groove of that surface. The trochlear centre forms the rest. In the dog the head of the radius corresponds to the extent of the capitellar centre of ossification.

This centre is homologous with the lower end of the femur, and hence the origin of the crucial fold is rendered more strictly comparable to that of the crucial ligaments.

I have great pleasure in tendering my thanks to Professor Macalister for his kindness to me in the progress of this paper.

ON THE TEMPORAL FOSSA. By EDRED. M. CORNER,
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Sussex College, Cambridge.*¹

IN looking through a series of skulls it will be noticed that the relations of the two temporal lines to the rest of the skull vary considerably. So I made a series of measurements and constructed suitable indices to show these variations. One would naturally expect these lines to vary with the shape and contour of the skull, and especially with degrees of prognathism,—the temporal muscle being of necessity more powerful when the lower jaw is heavier. I have made these measurements on 100 human skulls of different races, and in this paper have tabulated the results. In many skulls it is far from easy to trace both temporal lines, but with care this may usually be accomplished. The posterior portion of the superior temporal line is the chief offender in this respect, and in my tables I have rejected all cases in which the lines were too indistinct to furnish definite data. The investigation has proved to be more complex than I had anticipated. There are so many factors at work that unexpected combinations are found which make classification difficult. For example, while both dolichocephaly and prognathism are accompanied by an absolute lengthening of the temporal fossa, it is found where these are combined that the average index of the length of the fossa for prognathic skulls lies between those of mesognathic and of orthognathic skulls. This is an apparent contradiction, but I believe that it can be shown that this is due to the fact that in dolichocephalic skulls the length of the skull has proportionally exceeded the lengthening of the fossa to such an extent that such skulls have lower indices than either the mesaticephalic or the brachycephalic. The mesognathous skulls have higher indices than the orthognathic or the prognathic, which may be due to the fact that mesognathic skulls are generally of greater capacity than the prognathic, and in this way the indices have been raised.

At first I calculated the length and height of the temporal

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lines, and the least breadth between them in terms of the length, height, and breadth respectively of the skull, but the results I obtained were not definite enough to warrant my constructing indices. I then adopted Sir W. Flower's method of comparing the measurements with the basinasal length; this yielded the results which form the substance of this paper. The only published measurements I can find are in Topinard's *Anthropologie*, p. 800. His indices are calculated to the minimum frontal length. He cites two types which I have quoted later, one of a New Caledonian and the other of a Slav. He has only used the least breadth between the temporal lines, and not any of the other measurements of the fossa.

Method.

The greatest length of the temporal fossa, the greatest height of the superior line above the zygoma, and the least width between the corresponding crests of the two sides were the special measurements I have taken. These were measured with the craniometer, and the greatest height was also measured as an arc with the tape. This last measurement gives an indication of the bulging of the skull into the temporal fossa. The points for the measurement of the greatest length and least breadth are obvious. The vertical measurements were taken from the sharp ridge on the upper part of the transverse root of the zygoma, above the middle point of the temporo-maxillary articulation, to the highest point of the temporal crests.

I first calculated these measurements to the length, breadth, and basibregmatic height of the skull respectively. The vertical temporal chord I calculated to the vertical temporal height. This method of stating results was indefinite, owing to the number of factors complicating each index. The indices so obtained were arranged serially to the cephalic and gnathic indices. I then calculated the proportion borne by these measurements to the basinasal length. In this way I obtained more definite results. The indices I used are defined as follows:—

$\frac{\text{Temporal length} \times 100}{\text{basinasal length}}$	= long temporal index.
$\frac{\text{Temporal height} \times 100}{\text{basinasal length}}$	= high temporal index.
$\frac{\text{Bitemporal breadth} \times 100}{\text{basinasal length}}$	= bitemporal index.
$\frac{\text{Temporal height} \times 100}{\text{Temporal vertical chord}}$	= temporo-vertical index.

These indices I have termed superior or inferior according to their

reference to the superior or inferior curved lines. I examined a series of 100 male skulls of various nationalities, and the measurements were taken of the fossa of the right side.

I have tabulated the results so that the relation between the relative size of the temporal fossa, the shape of the head, and development of the jaws may be apparent.

TABLE I.

Variations with the Cephalic Index.

	Sup. Long Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.	Sup. Temporo- Vertical Index.	Inf. Temporo- Vertical Index.
Dolichocephali, .	124.3	86.9	93.8	109.9	76.8	103.6	103.8	102.2
Mesaticephali, .	126.9	85.7	106.9	112.2	77.8	117.4	104.5	102.8
Brachycephali, .	131.3	93.0	116.2	116.7	82.8	128.3	104.3	103.2
Dolichocephali, .	69.1	66.1	73.4	61.4	60.1	82.0		
Mesaticephali, .	68.9	65.9	78.5	62.3	58.9	86.4		
Brachycephali, .	74.3	65.7	74.9	65.0	62.4	82.0		

The first group of indices are calculated to the basinasal length. The second are obtained by means of my first method. I give the latter to show the negative value of their results. They do not agree with what would be expected, and show that the measurements on which they are based vary too much to obtain clear results.

In the first table it will be seen that the brachycephali head the lists in the first six indices; the other two indices I shall deal with later. The dolichocephali are at the bottom of this table. The brachycephali therefore exceed both the other classes in the relative length and height of their temporal fossæ. And, as we should expect, the temporal crests of the two sides are relatively further apart. These remarks apply to both temporal lines. As regards the two high temporal indices, the mesaticephali and dolichocephali for practical purposes agree. The length of the skull does not seem to proportionally affect the length of the temporal fossæ,—the dolichocephali having relatively shorter, and the brachycephali relatively longer fossæ than the mesaticephali. The length affects the height indices differently,—the dolichocephali have lower and the brachycephali relatively higher fossæ. From these figures it might at first be thought that the dolichocephali have smaller

and weaker temporal muscles, which is not the case, more especially as prognathism with its heavier jaw is usually associated with dolichocephaly. But it must be remembered that these results are merely relative, and that although the skull may lengthen, so will the temporal fossa, and the relative lengths be little disturbed. The second table, in which the results are given in ratio of the length, &c., show that these relative changes of length to length and so on are not great. These variations will be more fully discussed when the gnathic index is considered.

The two temporo-vertical indices, which indicate the bulging of the skull wall into the fossa, show no great variation in the three classes of skull. Hence this bulging seems to be fairly constant in amount. One somewhat obvious point they emphasise is, that the greater part of the bulging lies between the curved lines. This is seen by comparing the superior and inferior indices. The latter are always smaller than the former, at least in those cases in which the two temporal crests are far enough removed from each other to show an appreciable difference in the indices.

TABLE II.

Variations with the Vertical Index.

			Sup. Long Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.
Tapeinocephali,	.	.	125·9	81·1	105·1	109·1	76·4	113·1
Metriocephali,	.	.	127·2	87·3	105·5	114·6	80·3	114·5
Akrocephali,	.	.	127·5	89·1	112·4	110·4	78·5	125·5

The indices in this table were obtained by calculating the measurements to the basinasal length. The 100 skulls that I have examined were selected to give a fair number in each of the three classes of the cephalic index. And the vertical indices unfortunately fall very largely into the tapeino- and metriocephalic divisions.

The length of the fossa inclosed by the superior curved lines, superior temporal fossa, does not change very much relatively to the height of the skull. The akrocephalic skulls have the largest

superior index in height, showing that the temporal fossa also increases relatively in height. The width between the superior lines is about the same in the tapeino- and metrio-cephali, but greatest in the akrocephali. Hence the relatively low heads have their temporal crests approximated. This is interesting morphologically, as in the anthropoid apes, with very low skulls, the temporal crests meet in the middle line and form the sagittal crest,—the superior value of the temporal muscle over the other jaw muscles being obvious in heavy and protruding jaws. Hence their prognathism is a very powerful factor in the extension of the temporal fossa. The akrocephali are at the top of the list of the inferior bitemporal indices, agreeing with what I have said as regards the similar superior index.

The metriocephali have relatively the longest and highest fossæ, inclosed by the inferior temporal line, the inferior temporal fossa. The high and low skulls have nearly the same indices. This is not so easy to explain. Of the 100 skulls only 14 were akrocephalic. Hence the indices for these skulls may not have been obtained from observations sufficiently numerous to eliminate the influence of gnathism, shape of head, &c.

TABLE III.

Variations with the Gnathic Index.

	Sup. Long Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.	Sup. Temporo- Vertical Index.	Weight of Lower Jaw.
Orthognathous,	125·6	84·6	114·5	112·4	79·2	117·2	103·5	79 grms.
Mesognathous,	131·5	91·7	92·8	119·9	86·8	108·1	103·8	101·1 „
Prognathous,	127·0	87·3	104·3	114·4	81·0	113·8	103·2	108·5 „
Orthognathous,	69·7	67·4	77·3					
Mesognathous,	71·1	70·0	71·2					
Prognathism,	66·9	65·5	75·0					

The first table was obtained by the basinasal method, and the second by my first method.

On first principles one would expect to find the temporal fossæ varying directly with the strength of the jaws, *i.e.* weight, and with prognathism. Hence it is surprising to find the indices for prognathic skulls falling between those of ortho- and meso-

gnathic skulls in the first table. An explanation probably lies in the correlated shape of the head. Sixty-four per cent. of the prognathous skulls were dolichocephalic, several markedly so. As I have shown under the variations with the cephalic index that the dolichocephali are relatively smaller in all their indices, it explains why those of the prognathic skulls are very likely to be reduced. Again, prognathism is usually combined with tapeinocephaly. Thirty-seven per cent. of the prognathic skulls I examined were tapeinocephalic, and several were just mesocephalic. Hence here is, as I have shown when dealing with the variations with the vertical index, another reason, and a possibly less strong one, for the like reduction of the temporal indices of prognathic skulls. The depressing influence of dolichocephaly is shown in the figures I have given in the second table. In the first column the length of the temporal fossa is expressed in terms of the length of the skull, and the prognathic index is the lowest of all. It holds a similar situation in the second column, where the temporal height is expressed in terms of the basibregmatic height. Hence care must be taken in order rightly to interpret these indices. I have quoted the superior temporo-vertical index. This shows that the skull wall bulges relatively equally into the temporal fossæ in all three classes of gnathism. I have given the weights of as many of the lower jaws of the skulls measured as were available.

Several of the skulls present a simian approximation of the temporal ridges of their two sides. In the following table I give the indices of five such skulls, giving also the absolute breadth measurement between the temporal crests.

TABLE IV.

		Sup. Bitemporal Length.	Inf. Bitemporal Length.	Sup. Bitemporal Index.	Inf. Bitemporal Index.
1165	Dalmatian, . . .	80 mm.	95 mm.	56·2	66·1
1852	Vancouver, . . .	52 mm.	77 mm.	47·7	70·6
1406	Ancient Egyptian, . . .	85 mm.	98 mm.	76·5	88·2
1233	Syrian-Tabrût, . . .	86 mm.	102 mm.	79·8	94·2
2141	Australian-Victoria, . . .	74 mm.	87 mm.	71·8	84·4
*	New Caledonian, . . .	53 mm.	70 mm.		
*	Slav, . . .	180 mm.	184 mm.		

* Topinard's *Anthropologie*, p. 800.

Topinard gives these last two examples. The New Caledonian represents the simian type, and the Slav he gives as a human type. It will be noticed in my figures that the skull from Vancouver's Island has the smallest superior bitemporal index.

Two good examples, and illustrating the other extreme of bitemporal distance, are furnished by two Czech skulls.

1152	Czech, . .	112 mm.	119 mm.	133·3	140·2
1155	Czech, . .	118 mm.	137 mm.	128·2	148·9

TABLE V.

No. of Skulls.	Race.	Sup. Long Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.
16	Australian, . .	123·9	84·8	96·0	110·5	76·9	105·1
3	Kaffir, . .	133·6	87·2	102·0	114·8	79·1	115·0
2	Czech—Prag, . .	134·2	88·5	130·7	115·3	79·9	144·5
5	Austrian, . .	133·9	94·1	115·9	124·4	86·3	127·6
5	German, . .	134·9	96·2	100·0	117·3	87·2	117·4
3	Mussulman, . .	124·2	86·3	101·5	111·6	78·9	106·5
7	Low caste Hindoo, . .	127·2	87·3	100·3	119·5	79·9	111·1
3	Pathan, . .	124·8	91·5	103·7	116·6	83·6	113·8
20	Ancient Egyptian, . .	125·6	83·7	111·9	105·5	75·8	126·0

The indices in the above table are obtained by Flower's method. It shows that the Australians, with their two bitemporal indices, approximate most to the Simian type. The Ancient Egyptians, who curiously come near to the Australians in the other indices, differ markedly from them in their bitemporal indices. And, again, the relative area of origin of the temporal muscle is relatively greater in the Australians. The superior long temporal indices of the Kaffirs, Czechs, Austrians, and Germans are all between 133·6–134·9. It will be seen, however, that the other indices separate them. The Czechs, as would be expected from their great brachycephaly, separate themselves by their large bitemporal indices.

It will be noticed that a marked difference exists in the indices of the three groups of Indians given above.

In conclusion, I may add that the poststephanic rise in the temporal crest does not seem to have any correlation to the condition of clinoccephalism.

TABLE VI.
Cephalic Index.

Cephalic Index.	Sup. Long. Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long. Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.
65	123.5	90.7	80.4	111.3	77.3	97.9
67	121.8	79.4	101.4	107.0	72.3	106.4
68	128.8	85.6	89.7	118.1	76.4	99.3
69	132.6	90.2	87.6	117.9	61.8	96.3
70	119.6	85.1	96.7	108.5	76.4	107.1
71	126.1	89.7	91.6	114.7	81.4	107.2
72	134.4	92.2	88.8	106.4	82.2	100.4
73	121.6	83.7	105.6	107.9	96.1	114.1
74	131.0	86.2	102.9	102.9	77.1	112.3
75	128.0	86.5	108.3	115.0	78.4	117.8
76	126.4	85.5	107.7	111.4	77.4	116.9
77	119.4	84.1	101.1	109.9	76.4	115.5
78	129.8	86.7	102.3	114.9	81.1	114.9
79	129.2	85.8	115.4	110.7	76.0	126.0
80	125.2	86.0	111.9	115.5	79.3	121.3
81	124.1	84.6	120.0	108.2	76.2	126.0
82	135.6	96.4	103.2	121.4	87.5	116.0
83	130.5	95.0	105.5	114.5	85.8	120.0
84	135.4	98.2	112.3	126.8	91.0	126.3
89	141.3	93.5	128.2	115.2	72.0	148.9
90	127.4	103.6	133.3	115.5	87.0	140.2

TABLE VII.
Vertical Index.

Vertical Index.	Sup. Long. Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long. Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index.
63	112.7	70.8	106.8	100.0	66.6	110.8
67	130.8	84.7	100.1	107.6	83.6	109.0
68	123.0	83.0	106.0	113.0	76.0	114.0
69	130.9	90.6	99.4	115.3	81.8	108.3
70	121.1	69.9	112.3	107.5	72.1	121.1
71	126.4	87.8	106.0	111.4	78.2	115.7
72	126.6	88.6	94.6	114.7	80.0	107.0
73	129.1	86.8	123.9	115.7	82.0	120.5
74	131.5	88.6	99.6	118.6	81.8	108.1
75	125.6	88.8	100.4	114.5	81.3	111.9
76	123.1	83.7	109.3	109.3	76.4	124.9
77	128.1	91.1	100.9	100.5	80.9	113.5
78	121.3	81.0	109.1	106.5	73.0	119.0
79	129.0	95.0	115.0	120.0	86.0	129.0
83	117.1	85.0	109.1	110.1	80.1	116.2
88	141.3	93.3	128.2	115.2	72.8	148.9

TABLE VIII.
Gnathic Index.

Gnathic Index.	Sup. Long Temporal Index.	Sup. High Temporal Index.	Sup. Bitemporal Index.	Inf. Long Temporal Index.	Inf. High Temporal Index.	Inf. Bitemporal Index
80	132.0	85.0	124.0	119.0	74.0	135.0
83	128.6	88.4	105.7	121.0	80.7	115.3
89	116.8	81.9	100.8	109.1	74.5	109.9
90	124.5	85.1	103.7	114.2	78.8	114.5
91	126.8	90.0	96.5	109.4	82.5	109.4
92	124.5	82.7	114.1	112.4	76.5	121.8
93	132.0	87.4	107.5	111.4	78.7	119.3
94	126.8	85.7	102.5	114.2	88.8	112.9
95	117.0	80.9	107.2	103.2	71.6	117.7
96	124.5	84.0	107.4	109.0	86.8	114.0
97	128.3	88.1	110.9	114.1	78.6	121.5
98	129.1	90.8	97.0	128.1	90.2	115.5
99	127.5	82.6	96.4	111.3	77.9	109.3
100	130.5	92.1	100.0	112.9	83.8	110.5
101	139.1	94.0	98.7	127.5	87.2	109.5
102	...	99.0	72.2	...	95.0	96.0
103	125.9	87.9	96.7	112.3	81.0	107.1
104	127.9	82.7	100.8	112.2	76.5	110.8
105	129.3	92.0	122.7	117.3	88.2	131.4
106	125.1	89.0	103.6	110.1	86.5	113.3
108	118.0	88.0	82.0	107.5	81.4	98.2
110	112.7	70.8	106.8	100.0	66.6	110.8
116	151.1	101.0	117.9	141.5	92.1	130.0

THE PROCESSES OF THE OCCIPITAL AND MASTOID
REGIONS OF THE SKULL. By E. M. CORNER, B.A.,
B.Sc., Scholar of Sidney Sussex College, Cambridge.¹

IN the text-books of anatomy there has existed some confusion as regards certain processes on the contiguous areas of the basilar regions of the occipital and mastoid bones. Gray does not mention any processes paramastoid and paroccipital. Morris says that the jugular process may extend and form a process homologous to the paroccipital process of animals. Quain calls the prolongation of the jugular process the paramastoid process. Macalister terms the jugular process and its extension, paramastoid or paroccipital. Testut describes the jugular process as small in man and larger in many mammals, especially in the sloths and herbivora. He co-relates with this large jugular process the absence of the mastoid process in these mammals. He describes it as sometimes articulating with the transverse process of the atlas. And then he considers it as homologous with the paramastoid process of animals. He derives the name 'paramastoid' from the relation between it and the mastoid process. Thus it will be seen there exists considerable confusion as to the names applied to processes between the jugular and the mastoid in the animal series.

In all the text-books the existence of a process of the temporal bone on the inner side of the digastric groove is overlooked, although the existence at this spot of a definite ridge or process is of nearly constant occurrence. Out of 304 mastoid processes examined by me, it was absent in only 7 per cent. A similar crest, ridge, or process was present on the temporal bones of 20 monkeys (8 Simiadae, 6 Cebidae, 6 Cercopithecidae), and in 3 Lemurs' skulls. In consideration of the constant presence of this process, and to remove the confusion of names, I propose that the name 'paroccipital' should be confined to the downward expansions of the occipital bone, and that the name 'paramastoid' should be applied to the process at the inner lip of the digastric groove.

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I have examined this region in 152 skulls of various races, and find that the paramastoid process was distinct in 93 per cent. In 4 skulls it was posteriorly continuous with the mastoid process. As a rule, these processes are symmetrical; but when there is a want of lateral symmetry, it is commoner in the paramastoid than in the paroccipitals.

The paramastoid exists in four conditions:—(1) as a broken irregular line scarcely raised above the surface; this is occasionally found in females; (2) as a short rough ridge, not extending as far as the back of the stylomastoid foramen; (3) as a long ridge, rough or sharp, extending nearly to the stylomastoid foramen; (4) as a bullate distended ridge, into which air-cells extend. This ridge is flanked on its inner side by the groove for the occipital artery, internal to which there is often a ridge along the occipitomastoid suture, which defines the inner edge of this vascular sulcus. In a few cases this ridge was fairly sharp and distinct.

To the paramastoid process is attached, on its outer side, the inner border of the posterior belly of the digastric; and to the crest of the ridge the intermuscular septum, which underlies the digastric, is firmly rooted.

There is no necessary relation between size of paramastoid and size of mastoid, nor between size of mastoid and that of paroccipital. This, Hyrtl has pointed out; and my observations are in accord, and do not confirm Testut's statement that the paroccipital and mastoid are reciprocally related.

Not only is this ridge constant on the human skull, but it likewise exists in those of monkeys. I have found it very large in the orang, as also occasionally in the paroccipital process. Both paroccipital and paramastoid exist in *Cercopithecus* and *Cebidæ*.

Three skulls of lemurs were examined. In all three the two processes existed on a ridge, as in the three *Cebidæ* mentioned above. In *Indris brevicaudatus* and *Propithecus diadema* the summit of the ridge was situated at the paroccipital region. In *Cheiromys madagascariensis* the culminating point of the ridge was situated about half-way between the paramastoid and paroccipital regions. Thus it will be seen that the skulls of the three *Cebidæ* mentioned above and of the lemurs form a series.

There is a ridge common to both paramastoid and paroccipital processes. Either or both processes may be developed, or a probably conjoint process may be formed at the middle of the ridge, as in *Cheiromys madagascariensis*. From this it would appear that there is no fundamental difference between the two processes as far as they give attachment to muscles and fascia, and that they originally were one ridge of attachment continuous from one bone to the other. This conjoined process may be called either paramastoid or paroccipital, according as its largest part is mastoid or occipital. It is the parent process in lower animals of the two distinct processes in man and monkeys, the condition found in the skulls of the lemurs being intermediate.

A somewhat interesting proof of this assumption is to be found in the attachment of the origin of the digastric muscle to this paroccipital process in the horse. Hence the inner lip of the origin of the digastric muscle, which in man is attached to the paramastoid process, has moved inwards and become attached to the paroccipital process.

Among the Carnivora in the Felidæ, Gadow, in Flower's *Osteology of Mammalia*, p. 121, says, The "paroccipital process is flattened over the back of the bulla, being closely applied to the whole of its rounded hinder end, and projecting, as a rough tubercle, slightly beyond it." In the skull of *Felis pardalis* there exist two processes, projecting over back of the bulla from this 'paroccipital' process. The process between the mastoid process and the most internal of the two processes of the 'paroccipital' mass is probably the paramastoid process, the most internal process being the paroccipital process. A similar but less marked was seen in the skull of *Arctictis binturong*.

Among the Edentata, in two skulls of *Choloepus didactylus* there existed a small but definite process on the outer side of the paroccipital process. A similar process existed on the skull of *Bradypus tridactylus*. It is not possible to determine whether these are truly paramastoid processes, not only on account of the synostosed state of the skull, but also because the origin of the digastric muscle has as yet not been described in these types in terms of these processes.

Paramastoid and Paroccipital Processes, classified according to their state of development.

<i>Paramastoid process.</i>	No. of process in 152 skulls, i.e., 304 processes.	Approx. percentage.
Short rough ridge,	53	18
Long rough ridge,	82	27
Rounded ridge,	58	19
Flattened, wide, rounded ridge,	34	11
Long sharp ridge,	24	7
Small, ,, ,,	4	1
Irregular rough ridge,	9	3
Serrated,	4	1
As a spine or tubercle,	5	2
Bullate partly fused with mastoid,	13	4
Obsolete or ill-defined,	21	7

<i>Paroccipital process.</i>	No. of processes in 149 skulls.	Approx. percentage.
Rough, but fairly uniform on surface,	68	23
Smooth, ,, ,,	11	4
Spinose,	8	3
Tuberous,	210	70
Articulating with the atlas,	1	?

In one respect the paroccipital process was often variable, namely, in the extent to which the sharp ridge which forms the hinder boundary of the jugular foramen projected. As this ridge has rooted into it, the hinder wall of the sheath of the vessel's ossification often extends into the fibrous tissue in old subjects, giving to this ridge a trenchant edge.

THE ASTRAGALO-CALCANEO-NAVICULAR JOINT. By
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University of Cambridge.*¹

THE text-book descriptions of the joints and their connecting ligaments are perhaps more divergent than those of any other system in the body: this statement especially holds good with regard to the tarsal joints. In the case of the joint which forms the subject of this paper, the plan usually adopted is to describe the articular surfaces between the individual bones, to classify the ligaments accordingly, and only incidentally to notice that this, the most important of all the tarsal joints, is one in whose conformation three bones each take a share. This method undoubtedly leads to considerable confusion and often, to my own knowledge, induces misconception in the mind of the student.

Of all the diarthrodial joints the enarthrosis must be regarded as most closely approaching the ideal, on account of the extensive range and infinite variety of movement which such an arrangement allows. Specialisation in the direction of the resulting movement, however, is in most cases the important end which has to be provided for by the moulding of the articular surfaces, and consequently enarthroses are of rare occurrence in the body, the hip-joint being the most suggestive example.

If all the ligaments attached to the astragalus are severed, and the head of this bone removed from its socket, leaving the os calcis and navicularis *in situ*, the resemblance the astragalo-calcaneo-navicular joint presents to the hip-joint is most striking.

(a) In both cases a rounded head is received into a deep and extensive socket.

(b) In both, the articular surface of the socket is to a large extent cartilage-clad bone, but not entirely, the continuity of the bony surface being interrupted by other structures.

The acetabulum is clothed to a considerable extent by the thin expansion of the ligamentum teres covering the

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fat lodged in the fovea acetabuli and attached to the edges of that depression. The bony contributions to the socket of the astragalo-calcaneo-navicular joint are supplemented by the calcaneo-navicular ligaments.

(c) In both, in no position of the joint is the cartilage-clad surface of the rounded head wholly contained within the socket.

In dried specimens of the tarsus the bones are usually fastened together in such a way that the upper edges of the astragalus and navicularis are made to coincide, a condition which never actually occurs during life. A variable extent of the articular surface of the head of the astragalus, even in the position of forcible flexion of the ankle and abduction of the foot, is always above the level of the upper edge of the navicularis; consequently, a certain area of this surface is never in contact with the articular surface of the socket, but is always opposed to the surrounding capsule.

The more important differences between the two joints, as far as their anatomical features are concerned, are as follows:—

In the tarsal joint the osseous surface of the socket is discontinuous (being formed partly by the os calcis, partly by the navicularis), and consists of two parts, capable of a certain though small amount of mutual displacement, leading to variations in the shape and extent of the socket: in the hip-joint, on the other hand, there is no such discontinuity, and the shape and extent of the socket, as far as the osseous surface is concerned, is invariable. This distinction, however, is more apparent than real, as both the capacity and shape of the articular cup of the acetabulum must certainly be subject to variation according to the position and degree of tension of the ligamentum teres, the tension of this ligament influencing, as I shall presently show, the amount of fat lodged in the fovea acetabuli. The articular head of the astragalus more nearly approaches an ellipsoid than a spheroid, and its receptive socket is of a corresponding shape. The astragalo-calcaneo-navicular joint therefore, though resembling the hip-joint in the depth and extent of the receptive socket, must, from the shapes of the articular surfaces, be placed among the condylarthroses.

I beg to call special attention to the foregoing comparison between the astragalo-calcaneo-navicular and hip joints, as there

are certain features in articular mechanism common to the two, but to these I shall refer later, and will first consider the question, whether it is possible to formulate some definite plan on which the description of the ligaments connecting the astragalus, os calcis, and navicularis may be based, instead of burdening the memory with a long list of differently named ligaments, between which there is no apparent relationship.

In dissecting the ligaments about a joint, in order to determine their disposition, it is important to do so from every aspect, and not only to examine them superficially, but also, when possible, to investigate the surface they present to the joint-cavity. Dissection is trammelled by the canon of description to a much greater extent than one is aware. The anatomist is apt to too blindly follow the accepted description and methods of dissection, and thereby, often unconsciously, to fashion the structure dissected to the mould of the description. This, on the face of it, is unscientific. The human frame is to a large extent but clay in the dissector's hands—clay from which many an artificially isolated product can be modelled; and of all structures in the body, the ligaments are the most plastic in this respect.

In all diarthrodial joints the primitive disposition of the connecting ligaments is one of a simple capsule, the fibres of which connect the edges of the articular surfaces in a cylindrical fashion, and tend to pass in as direct a manner as possible from one bone to the other.

The ligaments of the astragalo-calcaneo-navicular joint may be described under two categories: on the one hand, the ligaments which maintain the integrity of the socket by connecting the bony elements together, and completing the socket where these elements are deficient; on the other hand, the ligaments which retain the rounded head of the astragalus within the socket, being attached on the one side to the neck of that bone, on the other to the margin of the socket, these bands constituting the investing capsule. As the socket in this joint is formed partly by the os calcis, partly by the navicularis, the former includes all the bands connecting these two bones together.

A. THE LIGAMENTS COMPLETING THE SOCKET, *i.e.*, THE
CALCANEO-NAVICULAR LIGAMENTS.

The usual text-book description distinguishes two such ligaments: the inferior or internal, and the superior or external, respectively. This arrangement is to a certain extent artificial, and the names do not at all express the value of the bands which they are intended to designate. A superficial examination would, I own, lead one to be satisfied with these terms, but to fully appreciate the calcaneo-navicular bands, the removal of the cuboid on the outer aspect of the joint must be effected, and this reveals the fact that they form a more or less continuous ligamentous stratum, which occupies no less than four aspects of the joint—external, inferior or plantar, internal, and superior or dorsal (partially), respectively.

This ligamentous stratum may, for the purposes of description, be divided into three parts. The division is to a certain extent a natural one, as the arrangement, extent, and disposition of the fibres of the three parts present certain important differences. The three parts may be termed inferior, external, and supero-internal.

1. *The Inferior Calcaneo-navicular Ligament.*

On the inferior aspect of the os calcis, between the sustentaculum tali and the cuboidal facet, there is a short and usually well-marked groove, continuous by the medium of a notch with the interval which occasionally interrupts the continuity of the anterior of the two articular facets for the astragalus on the upper aspect of the bone. This groove lodges and gives attachment to a thick bundle of fibres, which, passing forwards and spreading out in a fan-shaped manner, is attached to the inferior aspect of the navicularis. This triangular band exhibits a remarkable fasciculation (fig. 1), the diverging bundles of which it is composed being separated by intervals. The most external bundle of this band is the longest and strongest, and is attached to a well-marked tubercle on the navicularis.¹

¹ This tubercle is a very constant feature on the bone, and sometimes reaches a very considerable size, a navicular bone in the Anatomical Museum at Cambridge being furnished in this situation with a projecting process which is even

The dissection required to expose this ligament is a somewhat deep one, as it lies to a certain extent under cover of the short plantar ligament, and is covered by a comparatively thick layer of fat, from which processes protrude through the afore-mentioned ligamentous intervals into the articular cavity. If the upper

FIG. 1.—The astragalo-calcaneo-navicular joint viewed from below, showing the three parts of the calcaneo-navicular ligament.

(articular) aspect of this ligament is examined, it presents, in the undisturbed state, a somewhat peculiar appearance, this surface being covered by loose fringes of synovial membrane enveloping pellets of fat. A little dissection is necessary to expose the radiating fasciculations of the ligament, and it can then be readily appreciated that these fatty masses are directly continuous with the extra-articular fat through its intervals.

The interpretation of the arrangement of the fibres of this ligament is obvious. The strong thick bundles point to the fact that this ligament is subject to considerable tension, while the fasciculations indicate that this tension is not always equally

more prominent than the internal navicular tubercle, the well-known process giving attachment to the *tibialis posticus*. As this process receives no mention in the text-books, I propose to call it the *inferior navicular tubercle*.

felt by the ligament as a whole, but that different parts of it are subject to strains of varying intensity at the same time. The significance of the peculiar fatty relations of the ligament will be considered later.

2. *The External Calcaneo-navicular Ligament.*

The fibres of this ligament spring from the narrow rough surface on the os calcis separating the cuboidal from the anterior astragalar facet, this surface widening when traced outwards on to the upper surface of the bone, to which some of the fibres are also attached. The lowest fibres are very short, disposed in parallel fasciculations, with relatively wide intervals between them (figs. 1 and 2); they are separated by a fat-containing interval from the most external band of the inferior calcaneo-navicular ligament. The upper and more superficial fibres are longer and stronger, and do not, as a rule, exhibit fasciculation; they form the greater part of the band, which can be exposed by a superficial dissection in the sinus tarsi. A large extent of this ligament is deeply hidden in the interval between the astragalo-navicular and calcaneo-cuboid joints. Though I have termed this ligament external, yet the fibres are disposed in a somewhat oblique plane, the superficial aspect of the ligament being directed downwards and outwards.

3. *The Supero-internal Calcaneo-navicular Ligament.*

This ligament is inseparable from the inner fibres of the inferior calcaneo-navicular ligament, and consists of a quadrilateral band attached to the whole length of the rough border of the sustentaculum tali. The fibres of this band have a skew disposition: twisting upon itself, the band winds round that part of the head of the astragalus which occupies the interval between the sustentaculum tali and the navicularis, being finally implanted, partially on the inner aspect (tubercle), but mainly on the dorsal aspect of the navicularis. The superficial aspect of this ligament is somewhat difficult to investigate, (1) owing to the close adherence of a thick fascial stratum, in which the tendon of the tibialis posticus is embedded; (2) owing to its intimate connection with the internal lateral ligament of the ankle.

As the tendon of the *tibialis posticus* crosses the inner aspect of the supero-internal calcaneo-navicular ligament, it traverses a thick fascial stratum, the tissue of which has become condensed to form the walls of a canal transmitting the tendon, the floor of the canal being thickened by a deposition of cartilage. It requires great care to dissect away this fascial stratum, and to remove the deposited cartilage, in order to expose the proper calcaneo-

FIG. 2.—The socket of the astragalo-calcaneo-navicular joint viewed from above. Some of the longer and more superficial bands of the external calcaneo-navicular ligament have been removed. In the notch between the anterior astragalar facets on the *os calcis* is seen the rounded inter-articular ligament, which has been cut in order to remove the astragalus. To the outer side of this band, as it spreads out in the ligamentous floor of the socket, are the synovial fringes covering pellets of fat.

navicular fibres. When the supero-internal calcaneo-navicular ligament is exposed in this way, it is found to consist of closely aggregated parallel fibres, disposed in a continuous non-fasciculated sheet, having a well-defined upper edge in close relation to the astragalo-navicular ligament.

The anterior fibres of the internal lateral ligament of the ankle are usually described as being attached to the calcaneo-navicular ligament, but the mutual relationship between the fibres of the two ligaments is that of an interlacement.

The Internal Lateral Ligament of the Ankle-Joint.—The superficial dissection of this ligament presents the same difficulties as that of the calcaneo-navicular, owing to the close adherence of a fascial stratum which constitutes the sheaths (fibrous) of the flexor tendons—as they wind round the inner ankle into the foot, and the superficial layer of which is known as the internal annular ligament. Posteriorly, however, the distinction between the fibres of the ligament and this fascia may be fairly easily made; and in order to expose the former, the fascial sheet with the embedded tendons should be carefully dissected off from behind forwards. When the ligament is dissected out according to this method, it is obvious that the term 'deltoid' is a misleading one. The internal lateral ligament consists of a quadrilateral mass of vertical, coarsely fasciculated fibres, descending from the tibia to be attached posteriorly to the astragalus, anteriorly to the sustentaculum tali. It is true that the anterior part of this ligament is strengthened by adherent fascia, the forward continuation of which fills up the angular interval between the anterior edge of the internal lateral ligament and the upper edge of the supero-internal calcaneo-navicular

FIG. 3.—The inner aspect of the ankle and astragalo-calcaneo-navicular joints, showing the triangular area of interlacement of the fibres of the internal lateral and supero-internal calcaneo-navicular ligaments above the sustentaculum tali.

ligament (fig. 3), and that this fascia with the ligament may be fashioned into a deltoid arrangement stretching forwards as far as the tuberculum navicularis.¹ I think, however, that this adherent fascia, dense though it is, should be distinguished from the true ligamentous fibres which pass directly into the bone. The connection between the fascia and the ligament is obviously a secondary one, and

¹ Henle distinguishes the anterior part of this sheet as a separable tibio-navicular ligament.

the former must be regarded in the light of an accessory or supplementing structure. With this reservation, the true ligamentous fibres of the internal lateral ligament are limited anteriorly to the sustentaculum tali,¹ and, remarkably enough, are attached to the same extent of bone as the fibres of the supero-internal calcaneo-navicular ligament. In order to achieve this end, and as a kind of compromise between two ligaments, both of which seek attachment to the same bony surface, the vertical fibres of the internal lateral ligament interlace with the upward and forward passing fibres of the calcaneo-navicular ligament. The interlacement of the two sets of fibres may be proved by dissecting and cleaning the fibres of the calcaneo-navicular ligament at the expense of those of the internal lateral ligament, or, conversely. Without making such an arduous and destructive dissection, the interlacement becomes sufficiently obvious when forcible traction is brought to bear on the two ligaments alternately.

There is consequently above the sustentaculum tali a triangular area where the supero-internal calcaneo-navicular ligament is especially thick and strong, as in this situation its fibres are interwoven with those of the internal lateral ligament of the ankle (fig. 3). On examining the outer (articular) aspect of this ligament, it presents a smooth, even appearance where it is in contact with the inner aspect of the head of the astragalus, owing to the thick deposition of cartilage in this situation. This condition is undoubtedly due to the inwardly directed pressure so constantly exerted on this part of the ligament by the head of the astragalus.

Henle describes three ligaments connecting the os calcis and navicularis, but the descriptions of the three bands are placed widely apart in his text-book. He describes a common tibio-calcaneo-navicular ligament (which includes the supero-internal calcaneo-navicular ligament as described above), a lig. calcaneo-naviculare-plantare, and a lig. calcaneo-naviculare dorsale, which can be exposed by a superficial dissection in the sinus tarsi. My thanks are due to Professor Thane for having called my attention to articles by Arbuthnot Lane (*Guy's Hospital Reports*, 1887, p. 254, and the *Journal of Anatomy*, vol. xxii. p. 408), in which he distinguishes in the same way as I have done between an inferior and superior internal calcaneo-scaphoid ligament, and points out that the latter ligament is thickened to resist, with

¹ There is deep stratum of the internal lateral ligament attached exclusively to the astragalus, and the shorter fibres of which are exposed both in front of and behind the longer and more superficial fibres (fig. 3).

the tendon of the tibialis posticus, a tendency to an inward, and not, as is usually described, a downward displacement of the head of the astragalus.

B. THE LIGAMENTS CONSTITUTING THE CAPSULE OF THE ASTRAGALO-CALCANEO-NAVICULAR JOINT.

These bands, constituting the capsule of this joint, and which serve to retain the head of the astragalus within its socket, may be subdivided into the astragalo-navicular ligaments on the dorsal aspect, and astragalo-calcaneo ligaments on the lateral and posterior aspects of the joint.

The Astragalo-navicular Ligaments.

These ligaments occupy the interval on the dorsal aspect of the joint between the external and supero-internal calcaneo-navicular ligaments. Two such ligaments can be distinguished.

1. *Superficial*, which consists of a broad thin band stretching from the outer and slightly from the upper aspect of the neck of the astragalus, and inclining obliquely outwards and forwards, is attached to the dorsal aspect of the navicularis, some of its fibres being continued on to the middle cuneiform, supplementing the dorsal ligament of the joint between the navicularis and that bone. The most internal fibres meet the upper fibres of the supero-internal calcaneo-navicular ligament at an angle, and are interlaced with them at their attachment on the navicularis. The lower and more external fibres are stronger and thicker, sometimes tending to be fasciculated; the lower edge of this part of the ligament is usually in contact with the upper edge of the external calcaneo-navicular ligament. The whole ligament is very much longer than one would expect from an examination of the dried bones, as, in the first place, it is attached some distance behind the edge of the articular surface of the astragalus;¹ and, in the second place, it crosses that part of the

¹ The following areas may be distinguished in the upper aspect of the neck of the astragalus. In front of the edge limiting the tibial articular surface anteriorly there is a deep smooth groove, marked by vascular foramina, and lodging a pad of fat in the recent state; this groove is bounded anteriorly by a rough linear ridge, which gives attachment to the astragalo-navicular ligament; in front of this ridge, between it and the edge of the articular surface of the head of the astragalus, is a smooth surface, on which the astragalo-navicular ligament rests, without being attached to it.

cartilage-clad surface of the head of the astragalus which always projects to a greater or less extent above the level of the upper edge of the navicularis.

2. *Deep*, which consists of a shorter and less extensive set of fibres, attached to the upper and inner aspects of the neck of the astragalus. The fibres stretch forwards with a slight inclination outwards, and pass on to the navicularis, under cover of the superficial set, whose direction they cross. This ligament is usually to a certain extent under cover of the upper free edge of the supero-internal calcaneo-navicular ligament, the two ligaments being bound together by some loose connective tissue.

The astragalo-navicular ligaments are liable to a good deal of variation. There is sometimes present a third and still deeper set of fibres, which correspond in their direction to the fibres of the superficial set, and which consequently cross the direction of the fibres of the deep set under which they lie.

The Astragalo-calcanean Ligaments.

The ligaments connecting the astragalus and os calcis, and which take part in the formation of the capsule of the astragalo-calcaneo-navicular joint, are three in number:—

1. The external astragalo-calcanean ligament.
2. The internal astragalo-calcanean ligament.
3. The interosseous astragalo-calcanean ligament (partially).

It is concerning these ligaments that there is so much descriptive variance. I have consulted twenty or more text-books, English, French, and German, and there are no two which seem in any way agreed regarding either the nomenclature or disposition of these bands.

To quote a few examples:—In the last edition of *Quain*, the external astragalo-calcanean ligament is described as one in close proximity to, and parallel with, the middle fasciculus of the external lateral ligament of the ankle. Morris and Testut give corresponding names to this band, while it is described by Gegenbaur as the *ligamentum talo-calcaneum laterale*. Macalister describes the external calcaneo-astragalar ligament as a strong band occupying the sinus tarsi, this band being called by Henle the *ligamentum talo-calcaneum laterale*, by Gegenbaur the *ligamentum talo-calcaneum dorsale*, and by Weitbrecht the

ligamentum planum sinus tarsi. Remarkably enough, two such accurate observers as Macalister and Henle omit all mention of the more superficial and posteriorly situated band described in most of the English text-books as the external ligament. At first sight, therefore, it would seem as if in some cases the one, in some cases the other band had been overlooked, but apparently the ligamentum talo-calcaneum laterale of Henle is included by most authors in the comprehensive term 'interosseous ligament,' although Morris, evidently following Barkow, differentiates this band as the anterior interosseous ligament. These are but a few examples; but if the references given by Henle in his *Bandlehre* are consulted, it will be found that the names applied to the ligamentous bands in this region are endless.

I beg to suggest that if one or two points, which may be regarded as the ground-plan for the purposes of description, are kept in view, some sort of order may take the place of this bewildering confusion.

In the first place, it is important to distinguish as far as possible between the bands connecting the bones at the posterior, from those at the anterior astragalo-calcanean articulation, and to describe the latter in conjunction with the astragalo-navicular joint.

Secondly, when giving names to ligaments connecting any two tarsal bones, the name of the proximal bone should always be placed first.

Thirdly, for descriptive purposes, it is convenient to distinguish (as Henle does) between the sinus tarsi and the canalis tarsi. The canalis tarsi is the narrow tunnel towards the inner side of the foot: this tunnel abruptly opens into the extensive fossa of the sinus tarsi on the outer side.

Fourthly, the astragalo-calcanean ligament lodged in the sinus tarsi should (following Henle's nomenclature) be described as an external astragalo-calcanean ligament, as it occupies a lateral position with regard to the anterior astragalo-calcanean joint; while 'interosseous ligament' should be a term reserved for the astragalo-calcanean bands which are lodged for the most part in the canalis tarsi.

With this premise, I may notice here that there are lateral ligaments in connection with both the anterior and the posterior

astragalo-calcanean joints, and that the interosseous ligament is common to the two, constituting the posterior ligament of the one joint, the anterior ligament of the other.

In the posterior joint the *internal lateral ligament* is duplicate: one band passes downwards and forwards from the posterior internal tubercle of the astragalus to the hinder limit of the sustentaculum tali, and bridges over some of the fibres of the internal lateral ligament of the ankle; the other band passes downwards and backwards from the same point on the astragalus to the os calcis behind the sustentaculum tali, and completes the floor of the groove between the astragalus and os calcis lodging the tendon of the flexor longus hallucis; the fibres of this band are closely associated with those of the internal lateral ligament. The *external lateral ligament* is the one to which the term 'external astragalo-calcanean ligament' is usually applied (Quain, Gray, &c.). It is attached to the astragalus just in front of the fibular facet, and, passing downwards and backwards, is attached on the os calcis to the pointed (in well-marked bones) extremity of the tubercle which gives attachment to the middle fasciculus of the external lateral ligament of the ankle, by which it is partially covered. This ligament to a certain extent rides on the astragalus, as below its point of attachment to that bone it is lodged in a narrow groove just in front of the lower part of the fibular facet.

The lateral ligaments of the posterior astragalo-calcanean joint are very obliquely disposed bands, and thereby present a contrast to the nearly vertical lateral ligaments of the anterior joint.

The following descriptions refer to the ligaments of the anterior joint:—

The External Astragalo-calcanean Ligament.

This ligament is very accurately described by Henle. It is a strong band lodged in the sinus tarsi, attached above, to a well-marked tubercle on the inferior aspect of the neck of the astragalus, below, to the upper surface of the os calcis. It is often separated into two parts by a fat-containing interval. It has well-defined edges, the posterior edge being isolated from the interosseous ligament by an interval occupied by a fat-covered pouch of synovial membrane. Its fibres are disposed on a somewhat oblique plane, which meets the plane of the astragalo-calcanean fibres lodged in the canalis tarsi (interosseous ligament) at an angle. The superficial aspect of the ligament is in close relation with the origin of the extensor brevis digitorum, while the deep aspect faces the anterior astragalo-calcanean joint.

The Internal Astragalo-calcanean Ligament.

A deep dissection is required to expose this ligament, as it is under cover of the internal lateral ligament of the ankle and the supero-internal calcaneo-navicular ligament. It consists of a thin and somewhat variable band, attached above, to the surface of the astragalus just below the forepart of the tibial facet, below, to the sustentaculum tali. It is the band to which, I presume, Morris refers under the name 'antero-internal calcaneo-astragaloid ligament.'

The Interosseous Astragalo-calcanean Ligament.

This ligament is usually described as being exceedingly strong and of great thickness, and one has always been led to regard it as one of the most important connecting links in the tarsus. This idea requires some modification. The strongest ligament connecting the astragalus and os calcis is the external astragalo-calcanean (as described above); and if this is cut through, a comparatively inconsiderable force is required to rupture the connecting links between the two bones as far as the interosseous ligament is concerned.

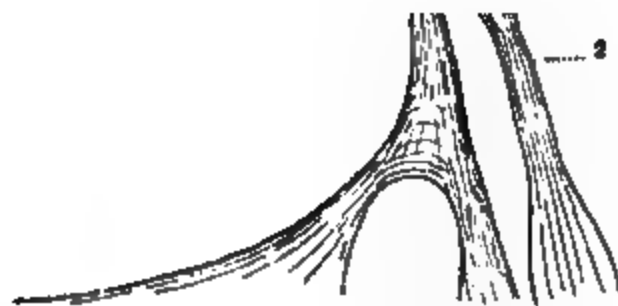
The interosseous ligament for the most part occupies the *canalis tarsi*; and if the grooves in the astragalus and os calcis, which together complete this canal, be examined, their appearance is certainly against the idea that they give attachment to strong bands. The degree of roughness presented by a bony surface giving attachment to a ligament is to a large extent the index of the strength of that ligament, and these grooves certainly do not exhibit any well-marked roughnesses, but are for the most part smooth surfaces, interrupted by vascular foramina, and lodging a considerable quantity of fat. Further, the *canalis tarsi* is largely occupied by another and altogether unexpected structure, viz., a deeply-situated contingent of the *ligamentum fundiforme*.

The ligamentum fundiforme, usually described in connection with the lower division of the anterior annular ligament of the ankle (*ligamentum lambdoideum*), is the sling-like structure which forms a pulley for the tendons of the extensor longus digitorum and peroneus tertius. This exceedingly well-marked sling has usually but scant attention paid to it in the text-books, and certainly no text-book

description leads to a proper conception of its strength, importance, and disposition. It was first described by Retzius (*Müller's Archiv*, 1841, p. 497), who, finding it in the dog, proved its existence in man; from his investigations it appears to be a very constant structure throughout the mammalia. His description of the deep attachments of the sling are somewhat obscure, and he only casually notices that a certain contingent passes into the "groove of the astragalus"; he mentions, however, that a part of it is attached to the os calcis as far as the sustentaculum tali, and evidently implies that it occupies the canalis tarsi, though he does not use this term. Retzius lays especial stress upon the importance of these deep connections of the ligament, but his description has apparently escaped the attention it deserves, and has not been incorporated in any later writings. I may add that I had worked out the disposition and connections of the ligamentum fundiforme before reading his paper, and practically came to the same conclusions.

The proper method of dissecting out this band is as follows:—The lower part of the anterior annular ligament must be isolated as usual from the rest of the deep fascia with which it is continuous. When this is done, the most strongly marked part of it is a well-defined band which stretches obliquely upwards and inwards across the front of the ankle from the os calcis on the outer side to the lower end of the tibia on the inner side. This band must now be cut through just to the inner side of the extensor longus digitorum, between it and the extensor longus hallucis, and the outer part of the band with the tendons reflected downwards and outwards. It at once becomes apparent that most of the superficial fibres of this (now reflected) band curve in deeply at the inner side of the extensor longus digitorum tendon, and, taking a recurrent course behind the tendons, pass into the sinus tarsi where they are attached to the os calcis, and thus complete a loop, which forms a perfect pulley arrangement for the tendons of the extensor longus digitorum and the peroneus tertius. The free end of the loop—that is, the point where the superficial fibres curve in deeply—is situated on the front of the ankle, and is held in place by three stays derived from thickenings of the fascia, and radiating from it to three bony points in the leg and foot. One passes downwards and inwards to the inner side of the foot, where it becomes continuous with the plantar fascia, though some of its fibres are adherent to the navicularis; a second passes upwards and inwards to the lower end of the tibia; the third passes upwards and outwards to the external malleolus. These three stays together with the ligamentum fundiforme constitute the ligamentum cruciatum (Weitbrecht), or, neglecting the weakest of the three, namely, the one attached to the external malleolus, the more familiar ligamentum lambdoideum. To fully investigate the deep attachments of the ligamentum fundiforme, the astragalus and os calcis must be sawn through in such a way as to expose the whole length of the canalis and sinus tarsi. There is some little difficulty in preventing the structures contained in the canal from being injured by this operation, and the better plan is to saw through the bones in a plane parallel

to, but somewhat behind, the long axis of the canalis tarsi, and then, by the aid of chisel and forceps, to expose the full extent of the canalis and sinus tarsi. The contained structures may now be systematically dissected from behind. By these means the ligamentum fundiforme may be exposed in its whole extent, and its deep attachments investigated (fig. 4). The two limbs forming the loop



Scheme of the fibres of the Ligamentum fundiforme.

- | | |
|----------------------------------|---------------------------------------|
| 1. One of the stays. | 3. Deep or internal limb. |
| 2. Superficial or external limb. | x Oval aperture transmitting tendons. |

of the ligament may be described as the superficial or external, and the deep or internal, respectively. On the outer side of and below the tendon of the peroneus tertius some of the fibres of the deep limb pass into the superficial limb, or there is an interchange of fibres between the two, and this completes an oval loop, through which the tendons are transmitted (fig. 4). After this interchange of fibres the two limbs may still be distinguished from one another as they arch downwards into the sinus tarsi. The superficial or external limb is a somewhat variable structure, which is widely implanted in the floor of the sinus tarsi. It tends to be coarsely fasciculated, the intervals between the fascicles being occupied by the fibres of origin of the extensor brevis digitorum. The deep or internal limb clings closely to the neck of the astragalus, and passing into the sinus tarsi behind the external astragalo-calcanean ligament, its fibres spread out fanwise, and usually separate into two bands—an outer, which passes vertically downwards and is attached to the floor of the sinus tarsi in close connection with the outer limb; and an inner, which passes nearly horizontally inwards into the canalis tali, where some of its fibres are attached to the astragalus, but the main part are attached to the whole

length of the groove on the os calcis, forming the floor of the canalis tarsi (fig. 4). Between these two bands of the deep limb there is an arched border concave downwards, and bridging over a fat-containing space. Very closely associated with and lying on a plane anterior to that of the deep limb is a ligament, which at its attachment to the os calcis is often blended with its outer band: passing upwards and inwards, it is attached to the groove on the astragalus, forming the roof of the canalis tarsi, and thus tends to cross the inner band of the deep limb obliquely. The disposition of these two obliquely crossing structures has given rise to the misconception of an intermediate part of the interosseous ligament, consisting of two astragalo-calcanean bands crossing each other obliquely, as described by Henle and others; they failed to recognise the connection between these bands and the ligamentum fundiforme.

FIG. 4.—A somewhat oblique section through the astragalus and os calcis, showing the arrangement and deep connection of the ligamentum fundiforme.

The above description may be taken as representing the usual disposition of the deep limb of the ligamentum fundiforme. I have dissected it, out in the manner described, in a good many joints, and have found it somewhat variable, both as regards the extent of its connections to the os calcis and astragalus, and the relation it bears to the obliquely disposed astragalo-calcanean ligament. In some cases this ligament tends to traverse the deep limb of the ligamentum fundiforme.

The deep limb of the ligamentum fundiforme, diving into and occupying the whole length of the sinus tarsi, supplies a natural separation between the fibres of the interosseous ligament

belonging to the posterior, from those belonging to the anterior astragalo-calcanean joint, the former lying behind, the latter in front of it. Behind the deep limb of the ligamentum fundiforme in the canalis tarsi there are vertically disposed thin bands, forming the anterior ligament of the posterior joint; when traced outwards, they become scanty, and in the sinus tarsi are usually deficient; in this situation, the synovial membrane of the posterior joint tends to be pouched, and is in direct contact with the fat lodged in the fossa. In front of the ligamentum fundiforme in the canalis there are, in addition to the oblique band already mentioned, some weak and irregularly disposed bands, which form with it the posterior ligament of the anterior joint.

Morestin (*Bull. Soc. Anat. de Paris*, 1894, pp. 1017-1021) points out the deep connections of the ligamentum fundiforme in the canalis tarsi, but he makes no reference to the paper published many years ago by Retzius, to whom the honour of this discovery properly belongs. Morestin comes to the conclusion that the interosseous ligament is "extremely powerful." With this conclusion I entirely disagree: on cutting through all the ligaments connecting the astragalus and os calcis, with the exception of those lodged in the sinus tarsi, I have easily ruptured the remaining ties between the two bones; and were we to include the external astragalo-calcanean ligament, relatively strong though this band is, with the interosseous ligaments, these connecting links between the two bones can in nowise be described as extremely powerful.

The Inter-articular Ligament of the Astragalo-calcaneo-navicular Joint.

In connection with this joint, there is one remarkable band which is very frequently present. Owing to its deep position and the difficulties that lie in the way of its demonstration, its presence, as far as I can gather from consultation of the literature dealing with this joint, has not been previously noted. I discovered it accidentally in demonstrating the socket of the joint: having cut through all the ligaments which I have described in this paper as constituting the capsule, I found that the head of the astragalus was not entirely free, but a band

still connected it with its socket. I have examined a large number of joints, and have found it so frequently present that I cannot but regard it as being a normal constituent of the joint. It is a band which occupies the groove between the two anterior astragalar facets on the os calcis, or a corresponding position when these two facets are confluent, being connected, on the one hand, with the head of the astragalus, on the other, with the ligamentous floor of the socket. It is very variable, and may be present in any one of the following conditions :—

1. A simple fold of synovial membrane reflected into the joint, attached above to the astragalus, and continuous below with the synovial membrane covering the pellets of fat invaginated into the joint between the fascicles of the inferior calcaneo-navicular ligament.

2. An isolated string-like band of synovial membrane, having the same relations to the astragalus and the synovial-covered pellets of fat, and resembling in some respects the ligamentum mucosum of the knee-joint. This condition I have found with confluent anterior astragalar facets.

3. A broad band of synovial membrane, lying isolated within the joint cavity, and having the same connections.

4. A condition resembling 1, in that a projecting fold of synovial membrane is present, but between its layers there are distinct ligamentous fibres connecting the head of the astragalus with the ligamentous floor of the socket.

5. An isolated synovial sheathed ligamentous band, which in some cases is a very well-defined rounded cord attached to the head of the astragalus close to the articular margin, and passing obliquely forwards and inwards in the groove between the two anterior astragalar facets spread out in the floor of the socket, where it is directly continuous with the calcaneo-navicular ligament (fig. 2).

6. In one case, there was a remarkably long band of the external calcaneo-navicular ligament, attached to the posterior exit of a very broad groove between the two anterior astragalar facets, and the ligament connecting the head of the astragalus to the ligamentous floor of the socket passed through the fibres of this band.

The object of this remarkable band is, at first sight, somewhat

obscure. In the first place, I should like to be able to state that this band, when it takes the form of a rounded ligament, is directly responsible for the presence of the groove which occasionally interrupts the articular surface on the os calcis; but, unfortunately, I have found cases where a well-marked groove was present, but there were no signs of a ligament.

The part which this band has to play in the mechanism of the joint is one which, in my opinion, corresponds to that of the ligamentum mucosum in the knee-joint, or the ligamentum teres in the hip-joint. The ligamentum teres, from its weak nature,¹ cannot be regarded as a ligament which is of any service, either in maintaining the relative positions of the femur and acetabulum, or for limiting the movements of the joint: it must, therefore, have some other function to perform. The head of the femur is not the segment of a perfect sphere; and although in certain positions it may be regarded as accurately fitting its socket, yet in other positions this exact correspondence must cease, and a tendency to a vacuum be engendered (thereby seriously interfering with the mobility of the joint), were there not some mechanism whereby the surface and capacity of the socket is made to vary in order to adapt it to the varying curvatures of the head of the femur presented to it. Such a mechanism is supplied by the ligamentum teres² and the extensive pad of fat lodged in the fovea acetabuli. The tension of the ligamentum teres varies according to the position of the head of the femur, and the varying tensions of the ligament must influence the fat that underlies it. This fat is directly continuous, through the cotyloid notch, with the extra-articular fat on the inner aspect of the joint, and consequently this affords a means whereby the amount of fat within the joint can vary; that such variations do occur may be directly proved by carefully exposing the extra-articular fat on the inner aspect of the intact joint, and then, if the femur is rotated in different directions, this fat at one time will be found to be sucked in, as it were, through the cotyloid notch, at other times to be protruded

¹ According to Macalister, this ligament ruptures with a stress of about 14 kilos.

² I include in the term 'ligamentum teres' the thin expansion covering the fat in the fovea acetabulum, and which is attached to the margins of the fovea. This expansion varies considerably in thickness.

from it. If the fat within the fovea acetabuli varies, the expansion of the ligamentum teres which covers it can also vary, and must be regarded as the variable factor in the socket, whereby the socket is adapted to the varying curvatures of the head of the femur presented to it, this adaptation being to a large extent determined by the movements of the head of the femur to which the ligamentum teres is attached.

In ascribing this function to the ligamentum teres, one difficulty presents itself. According to Krause, the cavity of a joint is invariable (*Der Binnenraum der Gelenke ist unveränderlich*), and by this I presume he means the capacity of the cavity within the limits of the capsular ligament of a joint; consequently, if this capacity is diminished in one direction by the intrusion of fat into the joint, there must be a corresponding increase of capacity in some other direction. This increase of capacity may be provided for by the stretching of the capsular ligament, but this is scarcely likely to be the case in the hip-joint. If the posterior aspect of the capsule of the hip-joint be examined at the back of the neck of the femur, a deficiency in the capsule will be found at the lower and outer border of the zona articularis, and through this deficiency a pouching of the synovial membrane takes place, this pouch of synovial membrane being closely connected with a pad of fat on the inner aspect of the great trochanter. There is therefore in this situation a spot where the extra-articular fat may be either pulled into or pushed away from the joint-cavity through a deficiency in the capsule, a deficiency which may be compared with that on the other side of the joint, bounded by the cotyloid notch and the transverse ligament. Whether, when extra-articular fat is drawn into the joint through the cotyloid notch, there is a corresponding protrusion through the deficiency on the posterior aspect of the joint, and the converse of this, I have not determined, but it is certainly possible.

I have made this long digression on the possible functions of the ligamentum teres as the intra-articular band which I have described in the astragalo-calcaneo-navicular joint may have a somewhat similar function to perform. But little lateral movement is possible at the ankle-joint, the movements of abduction (eversion) and adduction (inversion) of the foot taking place

in the sub-astragaloid joints, and in these movements the head of the astragalus rotates within its socket. When the foot is adducted, the head of the astragalus moves, relatively to its socket, in a direction upwards and outwards, a greater extent of the articular surface of the bone making its appearance above the level of the upper edge of the navicularis. Under these circumstances, a smaller amount of the articular surface of the head will occupy the socket, and the socket must undergo a corresponding diminution. This diminution may be effected to a certain extent by an increased pressure of the tendon of the tibialis posticus, the muscle which is chiefly responsible for the movement, on the inner aspect of the supero-internal calcaneo-navicular ligament; but in addition, the inter-articular band which I have described will, when present, have some part to play in bringing about this result. From the disposition of this band (fig. 2) it is obvious that it must be put on the stretch when the foot is inverted, and according to its condition (synovial or ligamentous) it will tend either to pull more fat into the joint through the intervals of the inferior calcaneo-navicular ligament, or to directly elevate and pull outward the ligamentous floor of the socket. There is therefore in this joint a mechanism whereby a variable socket may be constantly adapted to the varying amounts of the rounded head which occupies it, this adaptation being determined, as in the hip-joint, by a band which is attached on the one side to the revolving head, on the other to a factor of the socket capable of variation.

In conclusion, I will summarise the more important points to which I have called attention in this paper. A great confusion exists with regard to the nomenclature and methods of description of the ligaments connecting the astragalus, os calcis, and navicularis, but this confusion disappears by emphasising the fact that there are but two joints between the three bones, and by distinguishing the ligaments of the one joint from those of the other. In the posterior joint, the incomplete capsule is constituted by anterior, posterior, and lateral ligaments; while in the anterior joint, the calcaneo-navicular ligaments are to be described as completing the socket, the capsule retaining the head of the astragalus within the socket being constituted by the astragalo-navicular ligaments on the dorsal aspect, by

external and internal astragalo-calcanean ligaments on the lateral aspects, and by a posterior astragalo-calcanean ligament on the hinder aspect of the joint. Further, in the anterior joint there exists an inter-articular ligament, which, like the ligamentum teres in the hip-joint, serves to adapt the socket to the head of the astragalus in different positions.

HALICHÆRUS GRYPUS: THE GREY SEAL. OBSERVATIONS ON ITS EXTERNAL APPEARANCES AND VISCERAL ANATOMY. By DAVID HEPBURN, M.D., M.C., F.R.S. Ed.,
Lecturer on Regional Anatomy, University of Edinburgh.

ON July 3rd, 1895, an adult specimen of the grey seal was delivered at the Anatomical Department, University of Edinburgh, having been forwarded by the Rev. Dr Joass of Golspie, by whom the animal was found washed ashore and dead. Through the kindness of Sir William Turner, the specimen was put into my possession, in order that I might make some observations on its external appearances, and thereafter examine its visceral anatomy for points of interest.

I. EXTERNAL APPEARANCES.

The external configuration and colour of all marine mammalia are of great importance, because there is reason to believe that they undergo considerable changes during the growth of the animal from its foetal to its adult state. So much is this the case, that two individuals of the same species might present appearances so dissimilar as to admit the possibility of errors in classification. A detailed statement of the dimensions and colour-markings of the specimen under consideration is thus of value.

The animal was a male, and yielded the following measurements:—

	Ft.	Ins.
1. Length from tip of nose to tip of tail—		
(a) Between perpendiculars,	6	9
(b) Along dorsal curve,	7	7
2. Length from tip of nose to the most distant point of an extended hind flipper, measured along the dorsal curve,	8	9
3. Length from tip of nose to tip of tail, along the ventral curve,	7	6
made up as follows:—		

- | | | |
|---|-----|------|
| (a) From tip of nose to umbilicus, 5 ft. 2 in. | Ft. | Ina. |
| (b) From umbilicus to genital opening, 1 ft. 2 in. | | |
| (c) From genital opening to tip of tail, 1 ft. 2 in. | | |
| 4. Length from tip of nose to aural orifice, | 0 | 10 |
| 5. Length from tip of nose to anterior root of anterior
flipper, in a straight line, | 2 | 5 |
| 6. Anterior flipper (pectoral limb)— | | |
| (a) Length, | 1 | 1 |
| (b) Width at base, | 0 | 7 |
| (c) Width across roots of nails, | 0 | 7½ |

The *Manus* had five digits, each with a strong convex nail. The digits were webbed, and both surfaces were covered with hair. There was no groove between the pollex and index.

- | | | |
|--|-----|------|
| 7. Posterior flipper— | Ft. | Ina. |
| Width across roots of nails, | 1 | 5 |

The *Pes* had five digits each, with a strong convex nail. The first and fifth digits were larger than the others. The webs were covered with hair on both surfaces. They were grooved in the longitudinal direction, so that the toes lay in apposition.

- | | | |
|--|-----|------|
| 8. The <i>Tail</i> was triangular in outline :— | Ft. | Ina. |
| (a) Width at its base or root, | 0 | 4 |
| (b) Length along its sides, | 0 | 5½ |
| (c) Length from base to apex, | 0 | 4½ |
| 9. Greatest <i>girth</i> close behind anterior flippers, | 5 | 4½ |
| 10. <i>Girth</i> at the level of genital aperture, | 3 | 6½ |

The rapid diminution in circumferential measurement was therefore very pronounced, for in a linear distance of little more than 3 feet there was a loss of 1 ft. 10 ins. in girth, thereby emphasising the fish-like character of the trunk of this animal's body.

Two rudimentary *nipples* were situated one on each side of the ventral mesial line 5 inches behind the umbilicus, and at a distance of 4½ inches from each other. These were hidden from view by the hairy coat, and when exposed they presented a dark slate-coloured elevation of the integument, studded with stiff black hairs. They were not lodged in an integumentary recess or slit, such as is found in the porpoise.

Each *aural orifice* was $\frac{1}{4}$ inch in diameter, the opening being rounded and lined by dark slate-coloured integument, forming a soft puckered pad in relation to its anterior aspect. This pad occupied the mouth of the external auditory meatus, into which it sank quite readily, and thus acted as a valvular closing apparatus.

The *nostrils* were in the form of two vertical slits, situated on the front of the snout, and looking forwards. Each slit possessed thick and projecting labia, which gave the front of the nose the appearance of being grooved vertically.

The *mouth* was situated on the inferior aspect of the muzzle, and was overhung by the projecting snout. On each upper lip there were six or seven parallel rows of powerful horny vibrissæ, arranged longitudinally. The longest of these vibrissæ measured nearly 4 inches. There was no beard.

The *eyelids* and eyeballs had suffered considerable damage, and were not in a suitable condition for detailed examination. Above and to the inner side of each palpebral fissure there was a rudimentary eyebrow, which consisted of three horny vibrissæ, the longest measuring 2 inches.

The *anus* was a vertical slit, situated under the root of the tail. It presented thick lateral labia, studded with hairs.

COLOUR AND MARKING OF THE HAIR.

Standing at a little distance from the animal, the general tone of the colour was a silver-grey, which appeared lighter when viewed from the head end than when looked at from the tail end, and was actually much lighter on the ventral than on the dorsal surface. The general tone of colour was darker along the sides than on the dorsum, while everywhere a darker tone was produced when the hair was wet than when it was dry.

Examined more closely, the general colour was seen to be the result of the intermingling of light and dark patches of hair, whereby a mottled appearance was produced. The size of these different patches constantly varied, and their shape was quite irregular. Each dark patch had a central area of almost inky blackness, which shaded off radially until a light patch was reached, in the centre of which the colour attained its whitest tone. On the neck and throat these appearances were most marked,

because in these regions the individual patches were larger than elsewhere. In other parts of the hairy coat these appearances were not so pronounced, because they were somewhat obscured by the general mottling, resulting from the smaller size of the colour patches.

The various patches of both colours, although irregular in outline, had a general longitudinal elongation, whereby a slight approximation to stripes resulted. This appearance was more evident on the dorsal than on the ventral aspect, where it was lost in the general mottling due to the smaller size of the patches. On the whole of the ventral aspect a shade of yellow was added to the whiter hair, and this was the more noticeable since on the belly there was a preponderance of light hair at any rate. On the throat, where the light and dark patches attained their largest size, the former having a slight tinge of yellow, they did not present any longitudinal elongation. On the sides of the neck, the dark patches predominated.

On the chest, between the anterior flippers, there was a more uniform dark grey, and similarly over the face and muzzle, where the mottled character was very indistinct. The anterior flippers were dark silver-grey on their dorsal surfaces, becoming a mottled pale yellow towards their radial borders. On their under surfaces they were similarly marked, but were paler along the ungual margins. The hair did not quite extend to the free extremities of the claws.

The hind flippers differed from each other in their general appearances. The right one was much darker than the left, which was not only the paler, but also the more mottled of the two. The right one was shaded from velvety black with occasional white points, to mouse-grey with brown points. The hair of both hind limbs extended some distance beyond the free extremities of the claws.

The value of the foregoing account is much increased by contrasting it with the descriptions of four individuals of the same species, recorded by Sir William Turner in his memoir on the "Placentation of the Seals."¹ These specimens included: (1) an adult female, "which measured 6 feet 11 inches from the tip of the nose to the tip of the tail"; (2) her foetus—a male—which measured 19 inches between the same points; (3) a young male, 4 feet 7 inches long;

¹ "Placentation of the Seals," *Trans. Roy. Soc. Edin.*, vol. xxvii. pp. 238-239.

and (4) a young live male, nearly five months old. Of the female, Sir Wm. Turner says, "The hairy coat of the mother was lead-grey in colour on the back of the body and head, but on the back of the fore and hind limbs and at the sides of the neck the general tint was white with black spots. The belly also was white, and marked with numerous irregular black spots." In the case of the young male, shot at the same time as the last, there was a different coloration of the hair. "The top of the head and the back of the body were brown, interspersed with grey irregular patches; down the middle of the forehead was a dark brown stripe, with a lighter brown stripe on each side. The belly was ash-coloured, with brownish spots at the sides and anal end."

The young live male was "slate-grey coloured on the back, with scattered black spots, irregular both in size and shape. When the skin was wet, the slate-grey tint was darker than when dry. The muzzle was a lighter shade of grey. The belly was whitish-yellow, with irregular black spots. The grey colour of the back and the whitish-yellow of the belly shaded into each other along the sides of the animal, where the black spots were more numerous than on the back or belly."

The foetus, again, "was covered with straight stiffish hairs, the longest of which were about half an inch in length, and neither woolly nor fur-like. The hairy coat was yellowish-fawn-coloured, streaked with dark grey bands and spots. The hairs were firmly adherent to the skin," and when pulled out "no under coat of wool was to be seen."

Further, it appears that "when just born, the hair on the back and belly is yellowish-white, streaked with some faint grey stripes down the back. At the end of a week the hair is whiter than when newly born."

An analysis of these various statements and their comparison with the hairy coat in the grey seal now under description would seem to show that there is a distinct tendency for the animal to darken with age, owing to the development of dark patches, which have usually a black centre. At the same time, the ventral aspect remains much lighter than the dorsal aspect, thereby suggesting a distinctly fish-like character.

On the whole, we may consider the male to be decidedly darker than the female, more especially along the sides of the neck and body.

LENGTH OF THE HAIR.

Over the general surface of the body the hairs had an average length of from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, but were shorter in the regions of the face and muzzle, and longer towards the claws. On the

dry parts of the dorsum of the body the tips of the hairs curled upwards and forwards towards the head. There was no fur between the hairs.

CHARACTERS OF THE HAIR.

The individual hairs were twisted longitudinally, and apparently flattened. They were coloured after the manner of a porcupine-quill, being banded or segmented in light and dark portions. Frequently the hairs from a dark patch were light-coloured at their roots, and conversely the hairs from the lightest patches were dark at their roots. Occasionally, hairs were seen coloured in three segments. Dark patches presented a number of hairs with white tips, and light-coloured patches showed a certain number of hairs with dark tips, and hence the tone of colour resulting from the fusion of light and dark patches was the result of the proportionate mixture of light and dark coloured tips, with the addition of a yellow tone where that shade of colour was found.

MICROSCOPIC EXAMINATION OF THE HAIRS.

In order to obtain transverse sections which would be trustworthy, I had a rectangular metal framework constructed, on the opposite edges of which two slight notches were cut at points exactly corresponding in position. A small pencil of hairs was laid across the framework, and occupying the two notches. These hairs were fixed by clamping them down with another metal frame, slightly larger than the first. The whole apparatus was then embedded in melted paraffin. Afterwards, the metal frame was cut out of the paraffin mass, and the small block containing the hairs was carefully removed from the interior of the frame. Thereafter this block of paraffin was fixed upon a microtome, and the sections cut and mounted in the usual way.

Towards their free ends the hairs tapered to a fine point, but sections taken from about the middle of their length presented a very remarkable amount of flattening. In the matter of absolute size the sections varied very little, whereas in regard to the relation of the short diameter to the long diameter the proportion was fairly uniform, and in the ratio of 1 to 5. Taking

the short diameter as the width of the section and the long diameter as its length, the *index* was obtained as follows:—

$$\frac{\text{width} \times 100}{\text{length}} = \text{index}.$$

As the result of several measurements, the average *index* was 20. In view of the fact that an index of 100 would represent a perfectly cylindrical hair, it will be seen that the hairs under consideration were so very elliptical that they might be spoken of as flat. This character appears more distinctly when we contrast the above *index*—20—with the lowest index recorded by Topinard¹ for the human hair, by whom the index of five Papuans is given as 40, and the lowest human indices, which were those of two individual Papuans, viz., 34 and 28.

In the white hairs there was only a faint amount of pigment, forming a linear streak lying in the long axis of the hair-section; but in the dark hairs pigment-granules were scattered irregularly and uniformly throughout the entire section, the only colourless part being the double contour line formed by the surface epithelium.

¹ Topinard, *Éléments d'Anthropologie Générale*, 1885, p. 278.

(To be concluded in the next Number.)

ON THE HOMOLOGY OF THE DUMB-BELL-SHAPED
BONE IN THE ORNITHORHYNCHUS. By JOHNSON
SYMINGTON, M.D., F.R.S.E., *Professor of Anatomy, Queen's
College, Belfast.*

(Read in the Section of Anatomy and Physiology of the Royal Academy of
Medicine in Ireland, January 24, 1896.)

ALTHOUGH this curious little bone, situated in the snout of the duck-mole, has been examined and described by various anatomists, its homology is still disputed. The theories that have been advanced on this subject are, (1) that it represents the inner parts of the two intermaxillary bones; (2) that it corresponds to the prenasal bone in the pig; and (lastly) that it is an anterior vomer. The first-mentioned view has been supported by Rudolphi, Meckel, Owen, Cleland, Albrecht, Turner, and myself; the second by Owen and Flower; and the last by J. T. Wilson and R. Broom.

As Sir William Turner in a paper¹ in this *Journal* has given the earlier literature on the homology of the dumb-bell bone, and, in my opinion, has effectually disposed of the prenasal theory, it is unnecessary for me to refer to these aspects of the question. It may, however, be noted, that Sir Richard Owen, in his article "Monotremata" in the *Cyclopædia of Anatomy and Physiology*, originally supported the intermaxillary theory, but subsequently abandoned it, and in his *Comparative Anatomy of the Vertebrates* adopted the prenasal view; while Sir William Flower, after the publication of Turner's paper, gave up the prenasal in favour of the intermaxillary theory (see Flower and Gadow, *Osteology of the Mammalia*, 3rd edition, 1885, p. 244).

The dumb-bell-shaped bone is of small size, its total length being on an average about 8 mm., the greatest transverse diameter of the anterior nodule 4 mm., and of the posterior 6 mm., while the isthmus is only 1 mm. across. Further, it is not firmly fixed to any of the other skull bones. The determination of its precise relations by the ordinary methods of dissection is, there-

¹ "The dumb-bell-shaped bone in the palate of *Ornithorhynchus* compared with the prenasal bone in the pig," *Jour. Anat. and Phys.*, vol. xix.

fore, attended with considerable difficulty, and can only be thoroughly investigated when these methods are supplemented by serial section and microscopic examination.

In 1891, I published a paper ¹ in which the description of the bone was mainly based upon a study of serial sections; and Professor J. T. Wilson and Dr C. J. Martin in 1893,² and Professor Wilson in 1894,³ extended our knowledge of the form and relations of this bone by a very thorough and accurate description of the cartilaginous and osseous framework of the snout of the Ornithorhynchus. All these papers were accompanied by illustrations, so that we now possess the necessary data, so far as the anatomy of the dumb-bell bone is concerned, to enable us to compare it with the osseous elements of the anterior part of the face of the other mammalia.

The dumb-bell bone consists of two lobes, anterior and posterior, united, when seen from below, by a narrow isthmus, and Wilson describes a small forked process, projecting backwards from the posterior lobe, which he terms the vomerine spur. The isthmus is bounded laterally by the naso-palatine foramina. The ventral surface of the anterior lobe, the isthmus and the anterior part of the posterior lobe, are covered simply by the oral mucous membrane and submucous tissue, but behind these parts the bone becomes separated from the oral mucous membrane by a layer of cartilage. On this point I wrote as follows:—

“In the greater part of its extent the bone is covered on its oral aspect by mucous membrane and a thin layer of submucous tissue, but near its posterior extremity also by a layer of cartilage. This is effected by an extension inwards to the middle line of the plates of cartilage which at the naso-palatine foramina lie external to these openings” (*op. cit.*, p. 581).

Professor Wilson has specially emphasised the morphological importance of this relation of the bone, and has also shown that

¹ “On the Nose, the Organ of Jacobson, and the dumb-bell-shaped Bone in the Ornithorhynchus,” *Proc. Zool. Soc. of London*, 1891, No. xxxix.

² “Observations upon the Anatomy of the Muzzle of the Ornithorhynchus,” *Macleay Memorial Volume*, Sydney, N.S.W.

³ “Observations upon the Anatomy and relations of the dumb-bell-shaped Bone in Ornithorhynchus, with a new theory of its homology, &c.,” *Proc. Linnean Soc. of New South Wales*, 1894.

it is prolonged on the dorsal aspect of the palatine plates of the maxillæ, and that its vomerine spur extends backwards in relation to the ventral edge of the cartilaginous nasal septum above the internasal passage, and within about 2 mm. of the vomer. The extremities of the bifid vomerine spur are connected with the vomer by bilateral vomerine ligaments (Wilson).

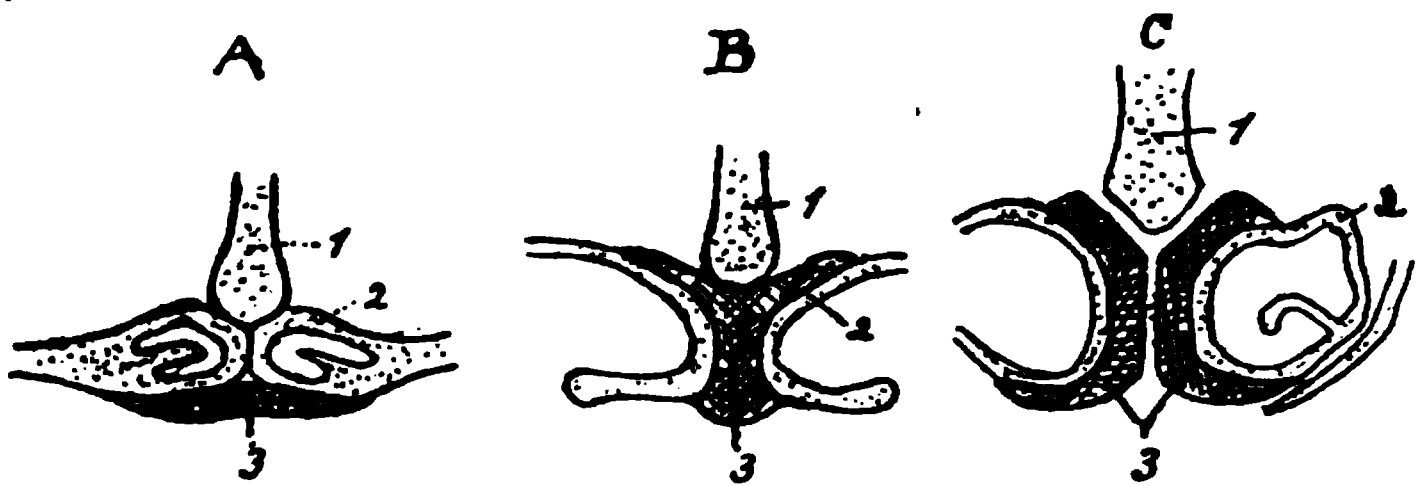


FIG. 1.—Coronal sections through the dumb-bell-shaped bone and adjacent cartilage $\times 8$.

A, through middle of anterior lobe; B, through isthmus; C, through middle of posterior lobe.

1, septal nasal cartilage; 2, cartilage investing Jacobson's organ; 3, dumb-bell-shaped bone.

The anterior end of the dumb-bell bone is flattened from above downwards, but in the greater part of its extent the bone possesses a well-marked median dorsal ridge. This ridge begins on the anterior lobe, and opposite the naso-palatine foramina is already well marked. Its dorsal edge divides into two lateral processes, so that on coronal section the bone appears as two crescents with their convexities directed inwards, while the external concave surface on each side lodges the inner part of the cartilage of Jacobson's organ. The lower or ventral horns of the crescent are very slightly marked opposite the naso-palatine foramina (see B, fig. 1), but about the middle of the posterior lobes both upper and lower horns are well developed, and reach fully half-way round the cartilage of Jacobson's organ. The dorsal aspect of the bone possesses a median depression, which serves for the lodgment of the ventral edge of the cartilaginous nasal septum. The fusion of the lateral halves of the dumb-bell bone is by no means complete. In my specimen, an adult female, they are united as far back as the naso-palatine foramina, in such a way that no trace of a median suture can be detected. Opposite the posterior part of the isthmus a median

fissure appears in the bone. This fissure begins on the ventral aspect, but is soon complete, so that the posterior lobes consist of two distinct lateral halves united merely by fibrous tissue.

The question of the homology of this bone must now be considered. As already stated, only two views need be noticed here, viz., the *premaxillary* and the *vomerine*. According to the former, "In its position and relations it corresponds with that part of the intermaxilla which lies between the incisive canal and the mesial palatine suture" (Turner). This is the part of the premaxilla termed the mesial palatine process, or the process of Stenson. Professor Wilson has brought forward various objections to this view, and contends that the dumb-bell-shaped bone "is a true 'anterior vomer,' formed, of course, by the fusion of two bilaterally symmetrical halves" (*op. cit.*, p. 138). He further holds that both in its palatine and in its nasal relations it corresponds to the palatine lobes of the vomer described by Professor Howes¹ as existing in *Caiman niger*. The situation of the dumb-bell-shaped bone in the palate internal to the naso-palatine foramina and the close relation of this bone to the organ of Jacobson are important points in favour of its homology with the mesial palatine processes of the premaxillæ of the mammalia, but the grounds on which Wilson objects to the premaxillary theory are deserving of careful consideration. In order to appreciate their force, it is convenient to regard the dumb-bell bone as consisting of a ventral portion more or less flattened dorso-ventrally, which may be termed the palatine plate, and a dorsal part which forms a vertical lamella, and enters into the formation of the nasal septum, although it must be distinctly understood that these two parts are directly continuous with one another, and show no indications of a line of separation.

The palatine plate of the dumb-bell bone does not, according to Wilson, lie in the same morphological plane with the maxillary palate, because its hinder end is covered ventrally by the cartilage of the nasal floor. This does not appear to me to be a cogent reason. The amount of bone covered in this way is

¹ "On the probable existence of a Jacobson's Organ among the Crocodilia, with observations upon the skeleton of that animal in the Mammalia," *Proc. Zool. Soc. of London*, Feb. 1891.

slight, and amounts to little more than an overlapping of the bone by cartilage. Further, Wilson and Martin have shown that the two large bones admitted to be premaxillary elements, which are situated in the lateral parts of the beak, and articulate posteriorly with the maxillæ and nasals, are traversed by the plate of cartilage forming the anterior and lateral portions of the beak of the *Ornithorhynchus*. In some situations this cartilage is merely embedded in grooves on the outer and inner borders of these two premaxillary bones, while in other situations the cartilage goes completely through the bone, and divides it into a dorsal and a ventral portion (see *Macleay Memorial Volume*, pl. xxiii. fig. 16). They suggest, I think very justly, that these premaxillæ are developed on both the ventral and dorsal aspect of this cartilaginous plate, which latter subsequently undergoes partial absorption. They do not, however, imply that each of these premaxillary bones represents two distinct morphological elements. It is doubtful if any morphological significance can be attached to this relation of bone and cartilage, and this significance is still more doubtful in connection with the existence of a layer of cartilage on the ventral aspect of the posterior end of the dumb-bell bone.

Wilson considers that the prolongation backwards of the vertical part of the bone on the dorsal side of the maxillary palate, and in close relation with the nasal septum, is opposed to the premaxillary, and favours the vomerine view.

Professor John Cleland, in his classical paper "On the relations of the Vomer, Ethmoid, and Intermaxillary Bones" (*Philosophical Trans. of London*, 1861), describes the position and relations of the mesial palatine process of numerous mammals. He referred to various cases in which this process extends, as in the dumb-bell bone, backwards on the dorsal aspect of the maxillary palatine plates. Thus, in connection with the skull of the Kangaroo, Cleland writes as follows:—

"The vomer exhibits on each side a peculiar lateral ridge, which extends forwards from the point where the vomerine lamina comes off and articulates in front with a very long prolongation backwards of the mesial process of the intermaxillary which extends between it and the maxillary" (*op. cit.*, p. 302).

Perhaps the most striking illustration of the backward pro-

longation of the mesial palatine process of the premaxilla on the dorsal aspect of the maxillary palatine process is to be found in the Tasmanian wolf (*Thylacinus cynocephalus*). In an adult skull of this animal, kindly placed at my disposal by my colleague Professor R. O. Cunningham, the total length of the mesial palatine process is 55 mm., and the portion on the dorsal aspect of the maxillary palatine process is 42 mm. long. In Flower's *Osteology of the Mammalia*, 3rd ed., p. 236, there is an illustration of a median section of a skull of this marsupial which shows very well this relation of the median palatine process, but is misleading in so far as its relation to the vomer is concerned, since it represents the posterior end of the process overlapping the dorsal edge of the anterior end of the vomer. This is not the case. The two mesial palatine processes form a median dorsal furrow which anteriorly lodges the septal nasal cartilage, and near its posterior end the anterior portion of the ventral edge of the vomer.

Figs. 2 and 3 are taken from a series of coronal sections through the snout of a pouch specimen of *Macropus major*.



FIG. 2.—Coronal section of Snout of *Macropus major*, immediately behind naso-palatine duct. 1, septal nasal duct; 2, cartilage of Jacobson's organ; 4, mesial palatine process of premaxilla.

FIG. 3.—Coronal section of Snout of *Macropus major*, posterior to fig. 2. 3, vomer; 5, palatine process of maxilla; other letters as in fig. 2.

They illustrate the relations of the mesial palatine processes to the palate, nasal septum, organ of Jacobson, and vomer. Fig. 2 is just posterior to the naso-palatine duct, and shows the dorsal extension of the process, internal to the organ of Jacobson, towards the nasal septum. In fig. 3, which is taken from a section further back, the maxillary palatine processes are seen on the ventral side of the mesial palatine processes, while the

lateral lamellæ of the vomer appear between the latter and the septal cartilage. It may be noted that the vomer is not really composed of two separate halves, as sections still farther back show it to be a single bone embracing the ventral edge of the nasal septum.

The backward extension of the mesial palatine process on the dorsal aspect of the maxillary palatine plate is not found in all the Marsupialia; thus, in a skull of *Phascolarctos* in my possession it terminates almost directly opposite the anterior edge of this palatine plate. On the other hand, in a number of Eutherian mammals the posterior part of the mesial palatine process will be found covered ventrally by the maxillary palatine process. In none of them, however, do they appear to do so to the extent found in the *Thylacinus*.

An interesting modification in this tendency of the posterior part of the mesial palatine process to disappear from the oral aspect of the hard palate is found in the Armadillos, as in these animals the lateral palatine plates of the premaxillaries extend inwards so as to meet in the median plane on the ventral side of the mesial processes. This is shown in fig. 4, representing a coronal section through the snout of a peba armadillo.

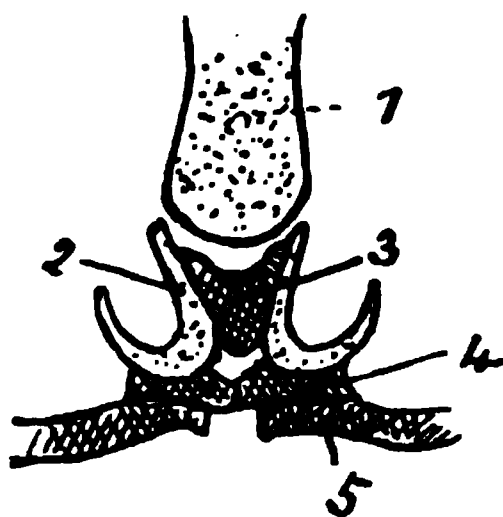


FIG. 4.—Coronal section of Snout of Peba Armadillo opposite Jacobson's organ. 1, septal nasal cartilage; 2, cartilage of Jacobson's organ; 3, vomer; 4, mesial palatine process of premaxilla; 5, lateral palatine process of premaxilla.

From these facts it is evident that the objection urged against the premaxillary theory by Wilson, on the ground that the posterior part of the dumb-bell-shaped bone is situated on the dorsal side of the maxillary palatine plates, is not valid.

As a rule, in mammals, the vomer extends forwards so as to articulate with the premaxillaries, the mesial processes of the

latter forming a median groove for the lodgment of the vomer. In the Ornithorhynchus this is not the case, as the dumb-bell bone is entirely anterior to the vomer, and is not, as Turner supposed, "inferior to the vomer, and fused with its lower border." This arrangement, however, is by no means peculiar to the Ornithorhynchus.

The two premaxillary bones, in mammals generally, exhibit very little tendency to become united by the ossification of the intervening connective tissue, whereas there is complete osseous union of the anterior lobes of the dumb-bell-shaped bone. In the 3-toed sloth, however, the tendency to fusion of the two lateral elements is more marked than in the duck-mole; for not only is there a single osseous nodule in the adult to represent the two premaxillary bones, but I have recently found from an examination of a foetal specimen that it is ossified from a single centre.

If the premaxillary homology of the dumb-bell bone be true, the Ornithorhynchus is unique amongst mammals in having its premaxillary bone permanently divided into two distinct portions—a mesial and a lateral. It is worthy of note, however, that in the 3-toed sloth only the mesial portion of the bone is developed, while in certain bats only the lateral part is formed. I consider that the evidence in favour of the homology of the dumb-bell bone of the Ornithorhynchus with the mesial palatine processes of the premaxillæ of ordinary mammals is conclusive; but the question now arises, Ought these mesial processes to be regarded as portions of the premaxillary bones, or should they be referred to the vomerine series, and called "anterior vomers"? The evidence that has been advanced in support of their being "anterior paired vomers" is based upon the belief that they are formed from centres of ossification distinct from those forming the main portions of the premaxillæ, and also upon data derived from comparative anatomy.

The late Professor W. K. Parker appears to have been one of the first morphologists to describe the existence of osseous elements in the snout of various mammals which he regarded as anterior paired vomers. Frequent references to anterior vomers and palatine processes of the premaxillæ will be found in his monographs "On the structure and development of the Skull

in the Mammalia" (pt. ii., Edendata, and pt. iii., Insectivora, *Phil. Trans.*, 1886); but, as Professor Howes has shown, "he was unable to draw a sharp distinction between the palatine processes of the premaxillæ and his anterior paired (or lateral) vomers." As a rule, when the process is short, he appears to regard it simply as a process of the premaxillæ; when long, it is called an anterior vomer; while in some cases, as for instance in the mole, he regards the process as mainly premaxillary, for the antero-lateral vomers "have a very temporary and doubtful existence independent of these processes of the premaxillaries" (*op. cit.*, p. 179).

The ossification of the whole or of the posterior part of the mesial palatine process from an independent centre has not yet been satisfactorily demonstrated except in a few instances. I will not attempt to discuss here the extensive literature bearing on the number of centres from which the premaxillary bone is formed, but may state that Dr F. Schwink¹ made complete serial sections of the snout of embryos of various mammals, and in only one case, that of a sheep 48 mm. long, did he find the centre for the palatine process separate from the body of the bone. Schwink very properly points out that it is easy to make sections showing the palatine process separate from the body, and that a complete series must be examined to determine whether or not it is really an independent centre.

I think it must be admitted that the mesial palatine process is generally formed, at least in part, as a process from the body of the premaxilla; and even although its posterior part may sometimes be developed from a separate centre, this is a very slender basis on which to assume that it represents an independent morphological element of the skull. The separate centre, if it exists, shows a remarkable tendency to fuse very quickly with the body of the premaxillary bone. In the entire mammalian series there is no animal, so far as I am aware, in which the mesial palatine process fails to unite with the body of the premaxilla should the latter be present. Again, there is no evidence that it fuses with the vomer so as to prolong that bone downwards and forwards to the hard palate in the region of the naso-palatine foramen. The vomer does, as Cleland has shown,

¹ *Ueber den Zwischenkiefer und seine Nachbarorgane, München, 1888.*

occasionally appear in the hard palate, but these cases are obviously due to imperfect development of the palatine plates of the maxillæ or palates. The most important evidence from the sub-mammalian vertebrata that has yet been advanced in favour of the vomerine nature of the median palatine process is contained in a suggestive paper¹ by Professor G. B. Howes. He shows that in an Alligator of Inter-Tropical America, *Caiman niger*, the vomer appears in the hard palate, so as to be visible from below between the premaxillo-maxillary sutures, where they are "inflated and bullate." In the other Crocodilia the vomers do not reach so far forwards as in the black caiman, and Howes found evidence that in them the vomer had shortened up. It was relatively long in young specimens, and in older animals a more or less powerful vomerine ligament passed from the anterior end of the vomer towards the place of meeting of the premaxillo-maxillary sutures where it blended with the periosteum. In a young *Alligator mississippiensis* he found two small foramina occupying very nearly the position of the palatine lobes of the *Caiman niger*. Within the embrace of these foramina he discovered a couple of small sacs with fibro-cartilaginous walls, and containing a "soft (? vascular) lining." There were no communications between these sacs and either the nose or mouth, and Howes concluded from their position that they were vestiges of Jacobson's organs. As these sacs occupied a position closely corresponding to the palatine lobes of *Caiman niger*, and as the mammalian palatine processes of the premaxillæ partly ensheath Jacobson's organs, Howes considers that we are justified in regarding, at least provisionally, these two processes as one and the same element.

A critical examination of the observations and suggestions made by Howes will show that the proofs he advances in support of his theory as to the homology of these two elements are by no means conclusive. The degree to which the vomer extends forwards, and the mesial palatine process backwards, varies considerably in different mammals, and Howes shows that this is also the case in the Crocodilia. Thus in *Caiman niger*

¹ "On the probable existence of a Jacobson's Organ amongst the Crocodilia, with observations upon the skeleton of that organ in the Mammalia," *Proc. Zool. Soc. of London*, Feb. 1891.

the mesial palatine process is absent, while the anterior end of the vomer is large, and forms what Howes terms its palatine lobe. In *Crocodylus palustris* the vomer does not appear on the oral aspect of the palate, but the mesial palatine process forms a spur of bone which is relatively larger in old than young specimens, and overlaps dorsally the maxilla. Howes regards, I think correctly, the vomerine ligament in *Crocodylus palustris* as a proof of the shortening up of the vomer, and he considers the mesial palatine process of its premaxilla as a mere secondary outgrowth, having little if anything to do with the palatine process as ordinarily understood. There seems to be no proof in favour of the view that the palatine lobe becomes detached from the vomer and joins the premaxilla, and it appears much more natural to assume that the appearance of the vomer in the palate of *Caiman niger* is to be correlated with the imperfect development of the palatine processes of the premaxillæ. Various examples are found in the skull of an element appearing in places where it is usually absent, this appearance being connected with its increased growth and the associated atrophy of the neighbouring elements.

The existence of a vestige of Jacobson's organ in connection with the palatine lobe of the vomer in *Caiman niger*, which constitutes one of the main grounds on which Howes homologises this lobe with the mesial palatine process of the premaxilla of mammals, seems to me to be somewhat problematic. Howes had no opportunity of ascertaining whether or not there was a rudiment of a Jacobson's organ in *Caiman niger*, as he did not possess a spirit specimen, while the sac he found in *Alligator mississippiensis* was exposed by ordinary dissection, and its relations and structure were not determined by microscopic section of this organ *in situ*. The view that this sac was a rudiment of Jacobson's organ must be accepted with reserve, since nearly all those who have searched for a Jacobson's organ in embryo crocodiles have failed to find any trace of it. It must be admitted, however, that Dr C. P. Slinter¹ has demonstrated its existence in the embryo of *Crocodylus porosus*. Even were it conclusively demonstrated that a rudimentary organ of Jacobson is situated in close relation with the palatine lobe of the vomer

¹ "Das Jacobson'sche Organ von *Crocodylus porosus*," *Anat. Anzeiger*, 1892.

of *Caiman niger*, this would not be conclusive proof of its homology with the mesial palatine process of the mammalian premaxilla: the organ of Jacobson does not appear to bear a definite and constant relation to any one osseous element of the skull.

The fibrous tissue found between the vomer and the dumb-bell-shaped bone in the Ornithorhynchus, Wilson describes under the name of vomerine ligaments, and regards as indicating the vomerine nature of the dumb-bell-shaped bone. He compares them with the vomerine ligaments described by Howes in various crocodiles, and appears to regard them as the fibrous representatives of the bone uniting two vomers, a posterior (vomer) and an anterior (dumb-bell-shaped bone). According to Howes, the vomer of the Ichthyopsida and lower Amniota, whether single or paired, is invariably a non-repetitional bone lying immediately behind the premaxilla. In the duck-mole the vomer is separated by a short interval (2 mm.) from the dumb-bell bone, and it appears to me more reasonable to regard the vomerine ligaments as an elongation of the sutural ligaments normally uniting the vomer and the premaxillæ, rather than as a vestige connecting a vomer which had become divided into anterior and posterior portions.

Dr R. Broom, in a paper "On the Organ of Jacobson in the Monotremata," which appeared in this *Journal*, Oct. 1895, assumes that the palatine processes of the premaxillæ in mammals and the dumb-bell-shaped bone are "anterior vomers," and the homologues of the "vomer" in lizards. From *Nature*, 15th Oct. 1895, I find that he read a paper before the Linnean Society of New South Wales on the 28th Aug. 1895, "On the homology of the palatine process of the mammalian premaxillary," but the journal containing this communication has not, so far as I am aware, yet arrived in this country.

[NOTE.—Since Dr Symington returned his proof for press the editors have received (March 23rd, 1896), through Dr Broom's courtesy, a separate copy of his paper referred to in the above paragraph. In it he accepts Prof. Wilson's view that the "dumb-bell-shaped bone belongs to the vomerine category, and is no part of the premaxillary." But, on the other hand, he considers that Wilson's arguments support and do not disprove its homology with the element usually called "palatine process of the premaxillary."

When once, he says, it is recognised that this palatine process "is itself a distinct vomer element ankylosed, or formed in connection with the premaxillary, the difficulty of reconciling the two views at once disappears." Broom suggests the name 'prevomer' as better than anterior vomer, and gives the following as its chief synonyms and homologies: prevomer = palatine process of premaxilla in mammals generally; dumb-bell-shaped bone in Ornithorhynchus; anterior vomer in Ornithorhynchus (Wilson): anterior paired vomer in foetal Insectivora, &c. (Parker): prepalatine lobe of vomer in Caiman (Howes): vomer in Lacertilia and Ophidia (Owen, Parker, &c.)]

WHAT IS SIBSON'S MUSCLE (*Scalenus pleuralis*)? By
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Bristol.

ACCORDING to *Quain's Anatomy*, p. 310, lines 18-23:—"The scalenus pleuralis (Sibson) consists of fibres which arise from the transverse process (? costal process) of the seventh cervical vertebra, and spread out in the fascia supporting the cervical

FIG. 1.—View of apex of right pleural sac from outer side, and above (†). P, dismembered scalenus anticus, or scalenus pleuralis, or both. SA, scalenus anticus; SM, scalenus medius; SA^r, subclavian artery; P, Sibson's fascia covering apex of pleura; R¹, first rib; C⁸, anterior division of 8th cervical nerve giving branch to P D¹, anterior division of 1st dorsal nerve; LT, lower trunk of brachial plexus.

dome of the pleura, by means of which they are inserted into the inner border of the first rib."

According to *Macalister's Anatomy*, p. 316, lines 23-26:—"A few spreading muscular fascicles, segmented from the lowest origin of the scalenus posticus, are attached to it (the fascia covering the apex of the pleura)."

So far as I know, these are the only English text-books which allude to the presence of this muscle, and it will be seen that the allusion is but slight in both.

Having myself often observed this muscle, or at all events something corresponding with it, I venture to describe what I have observed in the last two subjects which have come under my notice, because they have exhibited in a striking manner structures and arrangements which indicate that this muscle is perhaps not quite so simple as description at present would have us believe.

In one subject the conditions were these :—

On lifting up the scalenus anticus muscle and the third part of the subclavian artery, a long— $2\frac{1}{2}$ inches—muscular slip was seen passing downwards between the subclavian artery and the apex of the right pleural sac (? , fig. 1). This muscular slip, when fully dissected out, was seen to arise from the costal process of the seventh cervical vertebra, and to be inserted into the inner border of the first rib by tendinous fibres near the insertion of the scalenus anticus; but it was not wholly inserted there; many muscular fibres from its inner side passed to the fascia covering the apex of the right pleura, as shown in fig. 1.

Behind this muscle lay the anterior primary division of the eighth cervical and first dorsal nerves, which separated it from the scalenus medius muscle. According to the above descriptions quoted, this muscle is the scalenus pleuralis of Sibson, but it is a well known fact that a slip from the scalenus anticus muscle sometimes passes behind the subclavian artery; and as in this case the scalenus anticus muscle arose from the costal process of the seventh cervical vertebra, the question naturally arises: was this muscle the scalenus pleuralis of Sibson, or simply this partially dismembered slip of the scalenus anticus? It was innervated by a branch of the eighth cervical nerve.

If this muscle were simply an anomalous slip of the scalenus anticus, it at least sent fibres to the fascia of Sibson, and so far corresponded with Sibson's muscle.

But the second case may throw some light on the nature of this muscle.

This second example occurred in an old male subject on the table at the same time as the one exhibiting the first, and in it,

on performing a similar dissection, a muscle was found which resembled the first in that it lay behind the subclavian artery, but it differed from it in having two heads of origin and two slips of insertion (fig. 2, ?).

One head of origin arose from the costal process of the seventh cervical vertebra, the other arose from the neck of the first rib, and these heads of origin were separated from one another by the anterior primary division of the eighth cervical nerve (*vide*



FIG. 2.—The right pleural sac seen from above and the outer side (†). P, the muscle composed of slips A and B. Is A the dismembered part of the scalenus anticus, and is B the scalenus pleuralis? SA, scalenus anticus; SM, scalenus medius; P, apex of right pleura covered by Sibson's fascia; S, subclavian artery turned up; C⁸, anterior primary division of eighth cervical nerve; D¹, anterior primary division of first dorsal nerve; LT, lower trunk of brachial plexus; R¹, first rib; B_a, anterior slip of insertion; B_p, posterior ditto.

fig. 2). The head from the costal process of the seventh cervical vertebra was blended with the lowest slip of origin of the scalenus anticus muscle. Both heads united to form a belly, which after a course of an inch or so again divided into two slips of insertion. The inner slip (A, fig. 2) was inserted mainly into the inner border of the first rib under cover of the scalenus anticus, but some fibres from its inner side were inserted into Sibson's fascia. The outer slip (B, fig. 2) was inserted for the greater part into Sibson's fascia, only a few tendinous fibres

being prolonged to the first rib. We naturally ask ourselves what is the nature of this muscle; for we have here a muscle which, arising by two heads; one in conjunction with the lowest slip of the scalenus anticus, the other from the neck of the first rib, which is inserted by two slips, the inner of which runs mainly to the first rib, but partly to Sibson's fascia, the other, the outer, going mainly to Sibson's fascia, but partly to the first rib. Can it be that the part arising from the costal process of the seventh cervical vertebra in conjunction with the lowest slip of the scalenus anticus is the dismembered part of the scalenus anticus which was behind the subclavian artery and therefore tallies somewhat with the muscle described as Case 1? and is the other slip Sibson's muscle?

Whatever these muscles are, they appear to me to show that the scalenus pleuralis of Sibson is not quite so simple as text-books would have us believe; and it seems to be doubly difficult to understand how it can be a dismembered part of the scalenus posticus when it lies in front of the anterior primary division of the eighth cervical and first dorsal nerves. The only way in which it tallies with it is in its method of origin from the costal process of the seventh cervical vertebra; but as the scalenus anticus in both these cases arises also from the same process, it seems to me to have as great a claim to the scalenus pleuralis muscle as does the scalenus posticus.

On the opposite side, in Case 2, the muscle was small so far as its belly was concerned, but there was a well-marked tendon inserted chiefly into pleura fascia, partly into the first rib. Its origin blended with the scalenus anticus.

HEREDITARY POLYDACTYLISM.

By GREGG WILSON, M.A., B.Sc., Ph.D.

(Read before the Royal Physical Society of Edinburgh, Feb. 19, 1896.)

I HAVE recently become possessed of the facts of a large number of unpublished cases of hereditary polydactylism, and in this paper I propose to describe a few of these that seem to me to be of peculiar importance, inasmuch as they show considerable variation in the position of the abnormality. I shall also briefly review the evidence that is available for determining the cause of polydactylism.

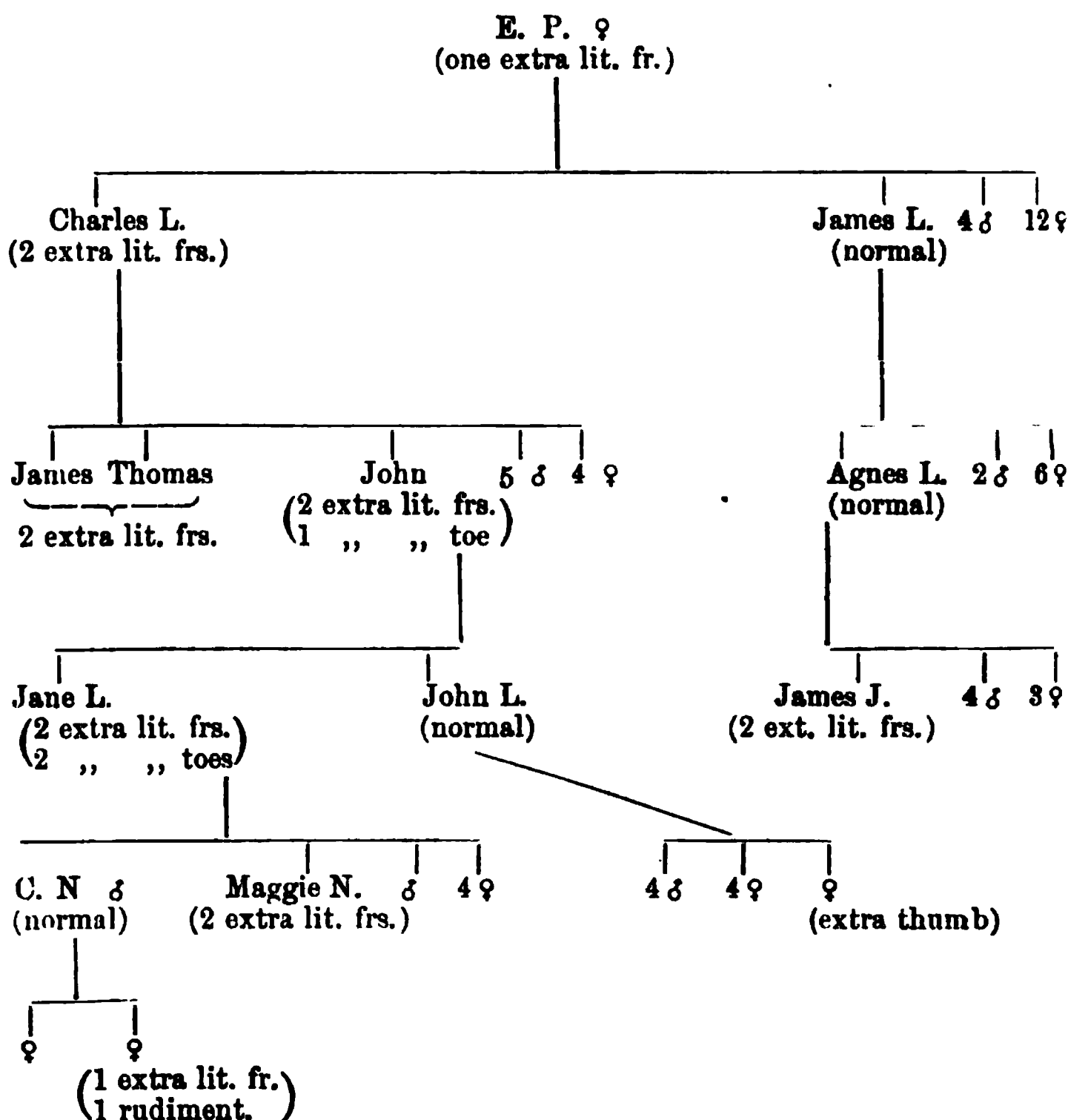
The first case that I have to describe is one to which my attention was called by Dr Fraser of Falkirk, who had removed an extra minimus from the hand of a child in whose family polydactylism was so common as to be expected. Fortunately a tradition existed to the effect that a book had once been written about the peculiarity; and this led to my finding an account of four generations of the family in Professor Struthers's paper "On Variation in the Number of Fingers and Toes" (1). Professor Struthers kindly handed over to me the original letters by Dr Hamilton on which he had founded his description of the Falkirk case, and at the same time gave me a large number of letters received by him with reference to other cases of polydactylism.

CASE 1.—The following are the leading facts of the Falkirk case, as I have been able to learn them from Dr Hamilton's letters, and from such members of the polydactylous family as I myself have seen.

E. P., "the first known ancestor with digital variety," had an extra minimus on one hand. She married A. L., and had eighteen children, all of whom, except one, are believed to have been normal as regards fingers and toes.

So far as Dr Hamilton was able to ascertain, the abnormality did not appear in the descendants of any of the seventeen normal children, except in one great-grandson of E. P. James L., one of E. P.'s normal sons, had two sons and seven daughters, one of whom, Agnes L., gave birth to a son, James J., with six fingers on each hand, and to seven other children who were all normal. I have been able to get full

information as to recent births in this branch of the family, and I find that no more abnormalities have appeared.



To return now to E. P.'s children: one of them, Charles L., was abnormal, having six fingers on each hand. He had twelve children, three of whom likewise showed digital abnormality. Two of these, James L. and Thomas L., had six fingers on each hand, like their father; and neither they nor their normal brothers and sisters seem to have transmitted any abnormality to their descendants.

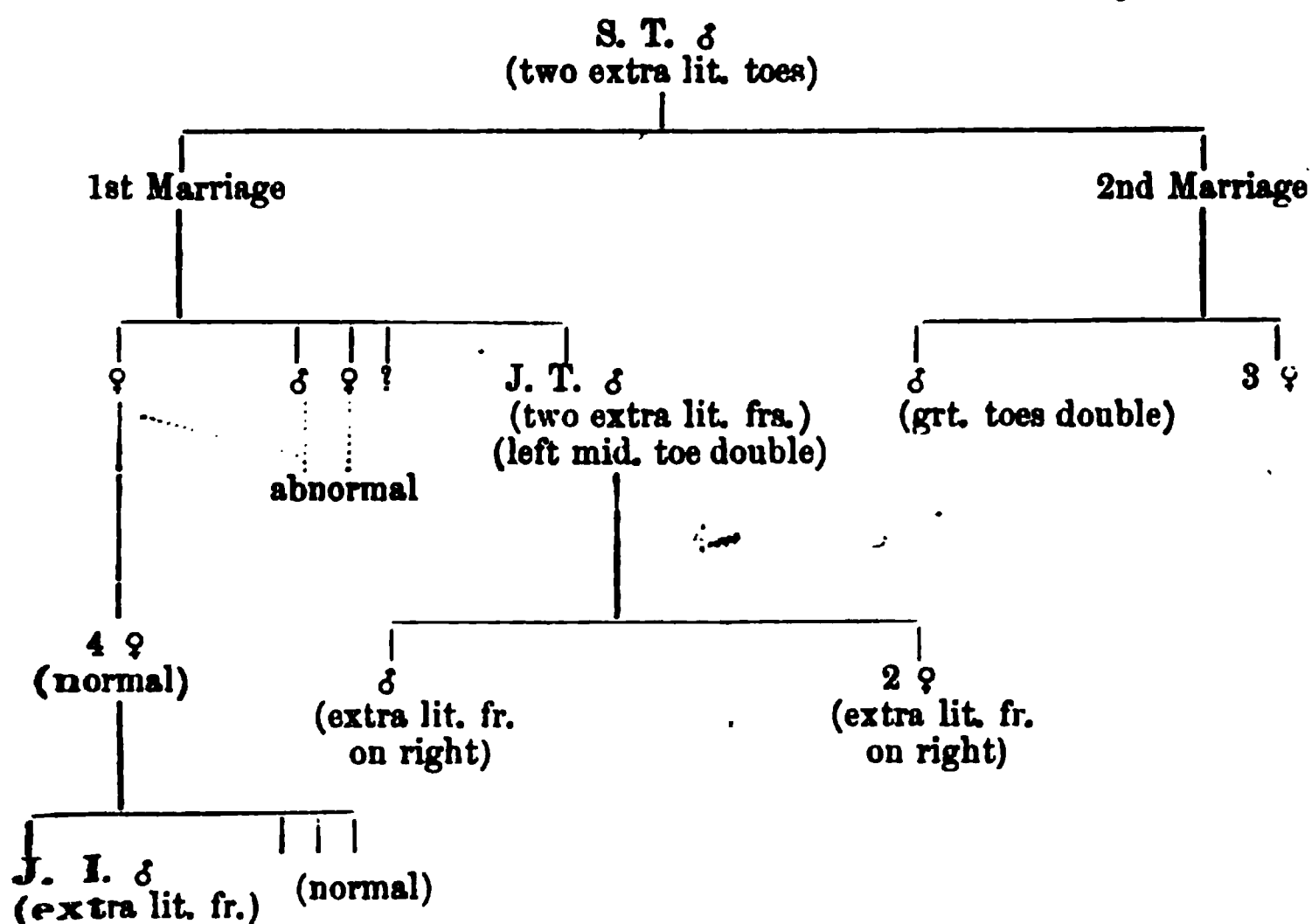
John L., however, the third of the abnormal sons of Charles L., showed increasing abnormality, having one extra little toe as well as two extra little fingers; and his descendants still show digital abnormalities. His only son, John L., though normal himself, is father of a child with the thumb of the right hand duplicated; and his only daughter, Jane L., was born with an extra minimus on each hand and six toes on each foot. She is mother of seven children, one of whom, Maggie N., was born with an extra minimus on each hand, while another, C. N., though himself normal, is father of a daughter who was born with one extra little finger and the rudiments of another.

The striking features of this case are the persistence of the abnormality through six generations, the increase of the abnormality in the first four generations, and the change in position of the abnormality from the post-axial to the pre-axial side of the limb.

CASE 2.—The second case is that of an Italian family of street musicians. The grandfather in this family had six digits on each hand and six toes on each foot. His son, N., has six toes on each foot and seven digits on one hand; and he had six digits on the other hand, but the supernumerary one was removed when he was young. The grandchildren are four in number, and three of them have six digits on each hand and six toes on each foot, while one, Tony by name, has an extra minimus on each hand and two extra toes on each foot, one of them apparently added on the post-axial side, while one is undoubtedly pre-axial, inasmuch as the innermost metatarsal bears two great toes. Except in Tony all the extra digits found in this family are minimi (figures 1 and 2).

In this case, as in the previous one, we find increase in the abnormality, Tony's father having two extra little fingers, where the grandfather had only one. And here, again, we have a change in the position of the abnormality from the post-axial to the pre-axial side of the limb, Tony himself showing both the original pre-axial addition and a duplicated great toe.

CASE 3.—The third¹ case is that of a Peebles family. S. T. had an extra little toe on each foot. He married twice. By his first



marriage he had a number of children, who are all said to have shown digital abnormality; and one of whom, J. T., is known to have had an extra minimus on each hand and an extra toe on the back of the middle digit of one of his feet. J. T.'s three children all showed digital variation, but only slightly: each of them had one small extra post-axial finger on one hand.

By his second marriage S. T. had one son with both great toes duplicated, and three daughters who were normal as regards digits.

In this case we see remarkable variability in the abnormality, a man with extra minimi on both feet having one son with extra great toes, and another son with extra minimi on the hands and a double middle toe on one foot.

CASE 4.—My fourth case also shows difference in the position of the digital abnormality found in the children of one parent. A woman, as the result of her first marriage, gave birth to a daughter, J. M., who had a small extra finger attached near the distal end of the proximal phalanx of the little finger of one hand. After her second marriage the same woman bore two daughters, one normal, the other having on the right hand two thumbs capable of slight separate movement, so that a small object such as a pin could be held between them.

CASE 5.—The fifth case I have to mention is that of another Edinburgh family. In the first individual in whom digital variation is known to have occurred, there was an extra finger attached to the proximal phalanx of the minimus of one hand. In the next generation, the only son showed an exactly similar peculiarity, while his sister had the great toe double in the right foot and partly double in the left. In the third generation the son's son is found to have an extra post-axial finger slightly attached to the proximal phalanx of the minimus of each hand, and an extra toe movable and well developed on the post-axial side of one foot.

All the cases that I have stated illustrate the variability of digital abnormalities; but in the great majority of cases of hereditary polydactylism with which I am acquainted, the abnormality is very constant in position, though not in degree. One is accustomed to see cases in which the abnormality consists in the duplication of one or more phalanges in one generation, while in another generation the duplication extends to the metapodial region; it is not even a rare thing to find the abnormality passing from the outer side of the hand to the outer side of the foot, and *vice versa*; but it is a rare, and I think remarkable fact that we have exemplified in the cases I have sketched—the passing of the abnormality from the one side of a

limb to the other. Had I met with only one case of the kind I should have been prepared to believe that the new position simply indicated a new and independent abnormality. But with so many cases, the probability against such a view is enormous. Maupertuis estimated that polydactylism does not occur so frequently as in one person in 20,000: if that estimate be taken for post-axial additions only, one may well assume that pre-axial additions, which are much rarer, are not so frequent as in one person in 100,000; and accordingly, the probability against a chance combination of these abnormalities would be as two thousand millions to one. So it is not likely that my five Scotch cases show two unconnected abnormalities; and we must look for an explanation of polydactylism that will account for the possibility of such migration of the abnormality as seems to be indicated.

I propose now to consider shortly the leading theories that have been suggested in explanation of polydactylism. These may be taken as falling into three groups: (1) theories that regard polydactylism as atavistic; (2) those that make it dependent on influences affecting the embryo from without, such as mechanical constriction by threads of the amnion; and (3) those that derive the abnormality from variation of the germ plasm, usually without assigning a cause for such variation.

I. The view that polydactylism is atavistic has been very commonly held in recent years. Darwin, in the first edition of his great work on *Animals and Plants under Domestication* adopted it, as he says, "with much hesitation," and chiefly because he supposed that the additional digits possessed the power of regrowth after amputation, like the normal digits of the lower vertebrata. He was confirmed in his view by the fact that the supernumerary digits are "strongly inherited," as well as by Owen's statement that some of the Ichthyopterygia had more than five digits. But in the second edition of his *Animals and Plants under Domestication* and in the *Descent of Man*, Darwin withdrew his former explanation, on the ground that it had been shown by Paget and others that the capacity for regrowth, that had been looked on as a primitive character, is found in normal bones, especially when amputated at an early age.

Nevertheless, the idea was not allowed to die ; and within the last few years von Bardeleben (2) has given it a new lease of life by the promulgation of his theory of the heptadactyle limb. He has recognised as "rudiments of præpollex and præhallux" certain bones on the inner side of the mammalian carpus and tarsus, that had previously been either quite unknown, or had been described as sesamoids. And these "rudiments," as well as the supernumerary bones (pisiforme and tuberositas calcanei), that occur on the outer side of the hand and foot, he has come to regard as representing digits that were formerly developed alongside of the five that are ordinarily recognised.

Rijkebusch (3) and Spronk (4) supported von Bardeleben's view ; and so did Wiedersheim till the palæontological evidence that seemed to favour it had been refuted. Baur (5) at one time seems to have been inclined to look for more than five digits in the mammalian limb, for he identified certain small bones in the tarsal region of *Cercolabes* and *Erethizon* as remnants of a sixth toe ; but subsequently his work on fossil *Ichthyopterygia* (6) deprived the heptadactyle theory of one of its chief supports. He proved that the oldest *Ichthyopterygia* had only five fingers, and therefore the extra digits of the later species were secondary structures ; a result that is the more credible as Kükenthal has shown that the sixth two-jointed finger of *Beluga leucas* is only secondarily split off from the fifth finger in the course of ontogeny.

Kollmann (7), while agreeing with von Bardeleben as to the primitive nature of the bones that he had identified as rudiments of digits, did not accept the theory of a primitive heptadactyle mammalian limb. He went back to the fishes for an explanation of the rudiments, and believed that they represented not fingers, but the fin-rays of an ancestral fish. Emery (9) took a similar view, but he recognised from his embryological work that certain of the bones in question are secondary structures. Albrecht (8) went rather further than either Kollmann or Emery, for he accepted not only extra-digital reversion, but interdigital, and showed that even the splitting of digits is atavistic, seeing that the fin-rays of the skates are normally bifid. He did not, however, believe in "true hyperdactyly" in man or other mammals that have normally five digits, for he maintained

that there were never more than five well-developed fingers present in mammals. In the horse¹ he recognised occasional true hyperdactyly, in man only false hyperdactyly or "atavistic dactyloschisis."

To the atavistic theories there are various, and as it seems to me insurmountable, objections, and there is no convincing argument in favour of them. Wiedersheim, in the second edition of his *Bau des Menschen*, points out that there is now no one fact of palæontology in favour of the view that terrestrial animals ever had more than five digits in hand or foot; and states that his embryological studies on the development of the limbs equally fail to favour the heptadactyle theory. Tornier (10), in an exhaustive work, endeavours to make it probable that not only some, as Emery admitted, but that all of the bones that von Bardeleben has regarded as rudiments of digits are of secondary origin, and not vestigial. Rüdinger and Zander both emphasise the fact that there is no evidence to show that the "rudiments" of von Bardeleben ever have any connection with the extra digits of polydactylous people; so that even if these rudiments are vestigial, it by no means follows that extra digits are atavistic. Gegenbaur attacks the idea that because polydactylism is hereditary, it is likely to be atavistic: undoubted malformations, such as defect of the clavicle, are transmitted. And Gegenbaur points out, too, that the great variation in the details of the abnormality is against the theory of reversion: sometimes the carpus of one hand differs from the carpus of the other to such an extent that the abnormalities cannot be looked upon as atavistic, unless we are willing to consider that the right hand has had one atavus, and the left hand another. Weismann completes this criticism by referring to the polydactylism of insects, where reversion is out of the question. I would only add, that as we are familiar with cases in which not only one or two, but many digits are added to one side or other of a hand or foot, and as we know other cases in which a limb is duplicated or triplicated, and others in which the whole hind-quarters or the whole anterior end is double, so it is not reason-

¹ The horse and mammals with fewer than five digits must be considered quite apart from mammals with the full typical number. It is now abundantly clear that reversion to remote ancestral conditions does occur.

able, without definite evidence, to conclude that the common cases of polydactylism are to be accounted for by atavism, which cannot possibly explain some of the other abnormalities that to all appearance are similar in kind.

II. I come next to consider the possibility of accounting for ordinary polydactylism by the action of external influences.

Ahlfeld (11) and Zander (12) are the two authors who have been specially associated with such a theory, and they both referred polydactylism to mechanical pressure of the amnion. Ahlfeld described a case of a child with a double thumb, due, as he supposed, to an amniotic thread that lay between the two thumbs; and Zander asserted that as the amnion had been proved to produce polydactylism in this case, it probably was the cause in all other cases. The theory partly commends itself, because we know of cases of deficiency of digits that have been traced to amniotic constriction; but, on the other hand, it is hard to reconcile the facts of any case of hereditary polydactylism with it. Zander explains that the inheritance may be due either to direct transmission of the effects of the injury done by the amnion, or to the transmission of the cause of the injury, *i.e.*, the malformed amnion. Zander favours the former view, though the transmission of characters acquired by adults is not believed in by him. He also points out that the transmission is always continuous, or that, at any rate, no more than one generation is passed over,—a circumstance that he regards as confirmatory of his opinion that the abnormality is an acquired character. But even if we could accept such a view as possibly correct, the difficulty that arises in many cases, as Fackenheim, Verrier, Weismann, and others point out, from the symmetry of the abnormality still remains. The gradual and symmetrical increase of the abnormality in the first four generations of my Falkirk case is undoubtedly not explained by amniotic constriction and the transmission of acquired injuries. It is perhaps worth while pointing out, too, that in the same case the transmission is discontinuous, inasmuch as the abnormality appears in James J. after passing over the two generations that intervened between E. P. and himself.

III. The third view of the origin of polydactylism, *viz.*, that it is to be ascribed to germinal variation, has been held by a

number of writers on the subject, such as Förster, Ziegler, Weismann, and Verrier. It is in reality implied, too, by those who have asserted that the abnormalities are due to atavism, for of course the abnormal development of rudiments of ancestral digits implies some other condition, some variation favourable to the unusual development of the rudiments.

It may be pointed out, that whatever the immediate cause of the abnormality, the history of a typical case of hereditary polydactylism is just such as one would expect, assuming it to be due to germinal variation. As a rule, the abnormality is constant in position, but varies in degree; it is transmitted generally only to a small proportion of the offspring of a polydactylous person who has married a normal person, and commonly it ceases to appear after a few generations; not infrequently it passes over one or two generations, to reappear in the second or third; at least one case, that of a village in France, is known in which by in-marriage the abnormality was perpetuated so as to become the normal condition of the people of a district.

But can we go further, and suggest a proximate cause for the peculiar presence of extra members? Verrier is willing to adopt the theory of either "progressive anomaly" or "regressive"; but the words hardly carry us further. Weismann, however, in his *Germ Plasm*, takes us to a nearer cause than "germinal variation," by the supposition that excessive local nutrition causes the duplication of the group of determinants representing the part that is doubled. The theory suits most cases of polydactylism. We can understand how the doubling of the primary constituents of a cell, or of a small group of cells, or of a large group of cells, may be effected by abnormal nutrition: we know how Gerlach and Dareste have succeeded in producing many monsters, including some double forms, by the modification of respiration and temperature conditions. We can understand, too, how the effects of a duplication of determinants would be handed on from generation to generation, till the abnormality was got rid of by the ordinary crossing of normal individuals with the abnormal; and we can readily conceive that the struggle of parts would result in a greater or less development of the abnormality.

To explain, however, such cases as I have described in this paper, something more than a mere duplication of the determinants of fingers or toes is required. The change in the position of the abnormalities has to be accounted for, and this is not possible without a slight modification of Weismann's theory. We may assume that there is variation in the *determinants that affect the nutrition* of the parts involved: in the case of excess of nutrition, a duplication of a few or many constructive determinants may result, and the abnormality consequent on such doubling will be hereditary in the ordinary way: it will be quite local. But the modified nutritive determinants may affect other and contiguous constructive determinants, and so a differently placed abnormality would result. I suppose that in some cases of hereditary polydactylism there is *not* transmission of the new determinants of the new digit, but rather transmission of the nutritive variation that gave rise to the abnormality. I conclude that, in my third case, the extra great toes of the one son and the extra middle toe of the other are in a sense new abnormalities, but are due to the hereditary nutritive abnormality that caused the original excess in minimi which appeared in various members of the polydactylous family.

It is important to observe that the theory of variation in the nutritive determinants would account for such abnormalities as the duplication or triplication of a limb, or for the doubling of the determinants of still larger parts, as well as for increase in the number of digits. It lets us conceive how essentially symmetrical variation is brought about; and the local struggle of parts is sufficient to explain the deviations from symmetry that are observable.

Of course, I do not pretend that the theory is complete; but I think it takes us one stage further towards an explanation; and no other theory accounts at all satisfactorily for such facts as those of the cases I have described in this paper.

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NOTE TO DR ELLIOT SMITH'S PAPER ON THE MORPHOLOGY OF THE TRUE "LIMBIC LOBE," &c.¹

IN the part of this paper published in the October number, while thanking the donors of material, I quite unintentionally failed to acknowledge the deep gratitude I owe to my friend Dr C. J. Martin, to whom I am indebted for some of the best material, which in many cases he collected at great personal inconvenience. Thus, all the Platypus material which was used for Golgi-impregnations I owe to him. I take this opportunity of thanking him not only for the material, but also for his valuable advice.

Since the paper was written I have examined a large quantity of fresh material, including a number of Echidna and Platypus brains. As a result, I find that the extent of flexion of the hemisphere in both Monotremes has been here underestimated, although not sufficiently to interfere with the general conclusions. Some of the statements referring to the hippocampus will therefore need slight modification; but as fresh figures would be necessary to intelligibly explain the corrections, it will be more satisfactory to defer it until the fuller paper is published. I hope then to be able to give a much clearer and more authoritative statement concerning the fornix than the limits of this paper (and the limitation of knowledge when it was written) would permit. For it is to the non-placental (so-called) mammals that one must look for the key to solve the perplexing problems of fornix morphology, our ignorance of which has been so plainly exposed by Honegger's memoir.

Ever since the Berlin Congress, Professor His has (nominally at least) adopted Professor Turner's nomenclature, although at the same time he retains Schwalbe's definition of a falciform lobe. His acceptance of Turner's rhinencephalon is, however, largely nominal, for he appears to confuse the ecto- with the endo-rhinal fissure, so that he really excludes the pyriform (*Archiv für Anatomie und Physiologie—Anat. Abth.* 1895, Supplement-band, p. 175, and 1892, v. and vi. Heft, p. 379).

In figure 1 of this paper (page 159 in the October number of the *Journal* 1895) part of the dotted line indicating the fascia dentata (*f.d.*) has disappeared in the process of reproduction. The fascia dentata, of course, lies *below* the hippocampal fissure (*h.f.*).

¹ This *Journal*, October 1895 and January 1896, p. 185. This note, dated University of Sydney, Nov. 22nd, 1895, was sent by Dr Elliot Smith with the view of its insertion in the January number of the *Journal*, but it reached the editors too late for insertion in that number.

SIXTH REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A.,
Professor of Anatomy in Mason College, Birmingham.

GENERAL.—Giacomini continues the series of papers on *Anomalies of Development*, which have been referred to from year to year in these reports. In the present (sixth) communication (I.) he deals with instances of (*a*) emigration of the embryo from the cavity of the amnion into the external coelome; (*b*) its emigration as a whole from all the foetal appendages except the chorion; (*c*) its emigration, with destruction of the chorion. The following is a summary of the conclusions drawn from this and the preceding papers. Abortions in the first two months are very common, and a careful study of them proves that the products of conception which they contain are seldom in a normal condition; the great majority of the ova contain deformed embryos, which His includes under the general denomination of abortive forms. From the study of such forms, it appears possible to divide them into two groups, according to the presence or absence of the embryo. Group I. contains those products in which not only is the embryo present, but as a whole, and retaining its usual relations to the membranes. This group includes two classes. Class i. Atrophic forms; those in which the embryo, though gravely altered externally and internally, still presents on microscopic examination obvious portions of organs. Here are placed all those forms which His has described as curved or cylindrical forms. Class ii. Nodular forms, in which the microscope reveals no traces of embryonic organs; very rare and difficult to study. Group II. Abortive products in which the embryo is absent. The absence may be accounted for in two ways: either the embryo has been absorbed *in situ*, or has emigrated from its natural cavity. Here, again, we have two classes. Class i. The embryo has been absorbed *in situ*; (*a*) but all the appendages of foetal origin are present, (*b*) all the embryonic appendages are absent except the chorion. Class ii. The embryo is absent because it has migrated from its cavity, (*a*) into the external coelome, (*b*) through all the membranes of the ovum as a whole, (*c*) wrapped in the amnion and with the umbilical vesicle, the chorion remaining in position, (*d*) passes by tearing through the chorion. (Note, references to the papers alluded to in this communication will be found in *Reports*, ii. 1, 2; iii. 2, 3; iv. 1, 2; v. 3; and also in a paper by the reporter in this *Journal*, xxviii. 436.)

In a paper on the *Teratoplastic family*, Féré (II.) refers to the theory of a neoplastic diathesis, founded by Verneuil on the fact that it is not rare to see several members of the same family affected with different tumours. Féré himself has seen tumours, such as lipomata, exostoses, &c., coinciding with congenital malformations of the bones or soft parts. Such deformities and tumours are met with in the families of several of these patients, but, in his opinion, the most significant fact is that these tumours and anomalies are met with only,

or with a marked predominance, on one side of the body, and seem to characterise a sort of trophic hemiplegia, which may be hereditary. Of this condition he gives several cases. With the idea of ascertaining whether any experimental proof of Cohnheim's theory as to the origin of tumours from fragments of included foetal tissues could be procured, he grafted embryos of chicks of different stages of development under the skin of full-grown fowls in various places. The result of his experiments went to show that most frequently absorption took place, but that sometimes, either immediately afterwards or after some interval of time, a development of tissue took place which was not differentiated at the time of implantation. It is therefore possible to conclude that embryonic elements placed in the midst of normally developed tissues are susceptible of ulterior development. The theory of the embryonic origin of certain tumours and the teratological theory of the heredity of tumours, and of their connection with maladies due to congenital predisposition, find an interesting support in these facts. In connection with this question, there may be mentioned a curious series of malformations occurring in a family, which is reported by Highet (III.). The parents were Malays, presenting no congenital defects themselves, who had had seven children in ten years, all of whom died in infancy: (1) absence of cartilage of left ear, (2) double harelip and cleft-palate, (3) absence of left fore-finger, (4) absence of left great toe, (5) no external malformation, (6) dermoid cyst of neck, (7) occipital hydrencephalocoele. In an elaborate series of papers, Meige (IV.) deals with the subjects of *Infantilism*, *Feminism*, and the *Hermaphrodites* of the ancients, respecting which subject he concludes that there exist in nature many corporal conformations, in which the morphological characteristics of the male are allied with those of the female in the same individual. These hybrid forms must be considered as abnormalities of development arising from a congenital alteration of the trophic centres which preside over the evolution of the sexual apparatus. Such defects of development may lead to any one of three conditions, viz., Infantilism, Feminism, and Virilism. A further study of some of the points relating to the same conditions will be found in a paper by Féré (V.). Koch (VI.) gives an account of two cases of malformations which he thinks are accounted for by an abnormal pressure of such a kind that if it existed at a sufficiently early stage, might cause serious malformations of the internal organs. In the first of his cases several of the bones were bent, and there was an atrophic condition of the skin and subcutaneous tissues over these parts. In the second case there was atrophy of the pectoral and other muscles around the shoulder-joint, with webbed fingers and other defects. Brissaud and Meige (VII.) give an account of a giant who, like McGrath (I.), was affected with *Acromegaly*: they add further cases to show that the combination of giantism and acromegaly is far from being an accidental occurrence, and finally conclude that acromegaly is the giantism of the adult, and giantism the acromegaly of the adolescent. Lampe (VIII.) gives an account of two cases of foetal rachitis, in the first of which the external signs of that condition were obvious, the large head with deeply indented nose-root, the extraordinarily short, fat extremities,

and the swollen skin with deep folds. In the skeletons the long bones showed highly vascular, knobbily thickened and expanded epiphyses; the diaphyses very short and thick and extremely sclerosed; between both were found here and there characteristic invaginations of periosteum. In connection with the ribs, highly anomalous formations were found at the junction of the cartilaginous and bony portions. A microscopic examination showed a very small amount of preparation in the cartilage for ossification, and a highly irregular process of ossification itself.

The external appearances of the second foetus were not so characteristic, though it possessed the indented nose-root, but the macroscopic and microscopic examination of the skeleton left no doubt that this case, as well as the other, belonged to the category called by Kaufmann, *Chondrodystrophia hypoplastica*. The special features of the first case were, (a) early synostosis of the sagittal suture, producing the condition of scaphocephaly; (b) a remarkable narrowing of the upper part of the spinal canal, which had produced complete compression and atrophy of the medulla and upper cervical part of the cord; (c) presence of sexdigitism on all four members. And in the second, (a) deviation of external form from normal rachitic type; (b) premature synostosis of the tribasilar. (For references to the lit. of this subject see *Reports*, ii. 3, also sub-refs. 2 at end of this report.) In respect to anomalies in general, Dwight (IX.), in discussing the significance of those which, met with occasionally or frequently in man, occur also in animals far distant from him in the genealogical tree, concludes that (a) similarity of structure, either in the ordinary animal or in the one showing variations, is not necessarily a proof of descent; (b) these very irregularities which we call abnormalities point to a law in accordance with which very diverse animals have a tendency to develop according to a common plan.

EXPERIMENTAL.—Féré (X.) contributes a study of the effect of *Temperature* on the development of the egg of the fowl, from which he concludes that the number of normal developments is about equal at 37° and 38° C., but that evolution is more rapid at 38°. At higher temperatures than this there are fewer developments progressively as the figure is higher: thus, there are at 39°, 38.09 p.c.; at 40°, 11.11 p.c.; and at 41°, 12.5 p.c. In general, those embryos which develop at 39° are further advanced at a similar period than those at 38°. Below 37° the number of developments again diminishes: thus at 36°, there are 59.45 p.c.; at 35°, 56.52 p.c.; and at 34°, 41.66 p.c. And at the same time that the numbers developed decrease, the proportion of monsters increases. Thus 38° C. is the best temperature for development, at least at the early stages; and experiments with alcoholised eggs prove that it is also that at which the resistance to external causes interfering with development is best marked. The same author (XI.) gives the result of his experiments on the shaking of eggs prior to incubation. (a) In 48 eggs shaken immediately before incubation, there were 3 absences of development, 15 monsters, and 30 normal embryos of 67 hours. (b) in 48 eggs shaken 24 hours before the process of incubation was commenced, there were 3 absences of development, 2 monsters, and 34 normal

embryos of about 91 hours. (c) In 48 eggs shaken 48 hours before incubation, there were 3 absences of development, 10 monsters, and 35 normal embryos of about 91 hours. (d) In 48 eggs of comparison, there were 4 absences of development, 3 monsters, and 39 embryos of about 97 hours. These facts show that mechanical vibrations have a retarding and teratogenic influence, which is much more evident when it takes place immediately before incubation than when it has happened at some period during the two days prior to the commencement of that process. The same author (XII.) exposed eggs to the vapours of ethyl, methyl, and amyl alcohols, all of which exerted a retarding effect upon development, though the first-named was the least harmful. In a second series of experiments, ethyl, propyl, butyl, and amyl alcohols, as also the iso-alcohol of each, were severally injected into the albumen of eggs. The results showed that in small doses ethyl alcohol was almost inoffensive, propyl, butyl, and amyl were progressively more so, and the iso-alcohols were respectively more harmful than their corresponding alcohols. In a further paper the same author (XIII.) gives an account of the incubation under normal conditions of eggs laid by two chicks hatched out from alcoholised eggs. Both series showed numerous different abnormalities, of which the 13 eggs of the second fowl may be given as examples: (a) blastoderm, without embryo or blood-islands; (b) normal; (c) primitive streak scarcely indicated; (d) blastoderm, without embryo and with arrested blood-islands; (e) omphalocephaly; (f) do. with double heart; (g) spina bifida; (h) cystic embryo; (i) normal; (j) omphalocephaly, with atrophy of head; (k) normal; (l) triocephaly; (m) normal. In two other papers (XIV., XV.) the result of the injection of various toxins into the albumen is given by the same experimenter; these experiments show that the same dose of a toxic agent which has up to the third day a decreasing teratogenic power, whilst permitting the embryos to survive, from that epoch exerts a toxic action, which is manifested by a mortality which decreases as its intervention is delayed. The teratogenic action coincides with one of an arresting character, which manifests itself still later when the mortality diminishes. It is not without interest to remark that whatever may be the period at which the toxic agent is introduced, and whatever may be its teratogenic or toxic action, embryos are often met with which resist its influence and continue to survive. These facts prove once more the reality of that individuality of the germ on which Dareste has so properly insisted, and which one sees exhibited also by remarkable exceptions in human degenerations. Morgan (XVI.), following Roux's (3) method of destroying with a heated needle one of the two first spheres into which the frog-ovum divides, found that the result was different in accordance with the position of the white pole, whether upwards or downwards, after the operation had been performed. He operated on 155 ova, from which he obtained 8 embryos. In most cases he had turned the white pole upwards, but from those so treated he only obtained two embryos. These two were perfectly formed, having both right and left medullary folds, though each of them was only one-half the size of a normal embryo. Of the other six, obtained from ova in which

the black pole had been left uppermost, all presented only one side, right or left, of an embryo, as in Roux's cases. He concludes that the position in which the egg is placed after the operation is an important factor in determining whether a half embryo or a whole embryo of half size will develop from one of the two first blastomeres. He thinks that the phenomena of half or whole development of an embryo from one of the first two blastomeres is entirely a protoplasmic phenomenon. The results have nothing to do with a qualitative division of the egg at the first cleavage, or with a later post-generation. Whether we get a half or a whole embryo will depend upon the subsequent arrangement of the protoplasm in the uninjured blastomere, and upon the relation of the protoplasm of the uninjured and injured halves. If the egg is turned after one blastomere has been injured, so that a rotation of the contents of the uninjured blastomere takes place, then a whole embryo tends to develop. The completeness of the development will depend upon the extent of the rotation. If the egg after the operation retains its normal position, then a half larva will develop. In a postscript, he states that he subsequently obtained five half embryos of the Roux type from 92 eggs when the black pole remained upwards after the operation. When the white pole remained upwards after the operation the results were not uniformly the same as those described in the preceding account. Seven whole embryos of half size and three half embryos were obtained from 125 eggs. In one of these latter the (half) medullary fold was for its whole length quite white in contrast to the dark ventral region. This shows that a rotation of the protoplasm (beneath the egg coat) must have taken place, without however producing a whole embryo of half size. We must therefore conclude that the rotation of the protoplasm is not the only factor determining whether a half embryo or a whole embryo of half size is produced. The results show, nevertheless, that after the rotation a larger percentage of whole embryos of half size are obtained than of half embryos; and further, that in those cases in which the black pole remained upwards, half embryos alone were obtained.

DUPPLICITY.—Duval (XVII.), in a most elaborate article, deals with the question of *Monsters* by excess and defect. In his opinion, polyspermia is the chief, if not the only, cause of redundancy of development. He commences his argument by endeavouring to show that the so-called dermoid cysts of the ovary are really imperfect foetuses, parthenogenetically produced. In this connection he cites a very remarkable case contributed by Répin (4), where a dermoid cyst contained a rudiment of a foetus provided with four unequal members, and terminated by a kind of head composed of bones arranged in a cube and provided with three teeth. The bones of the hands and feet were formed with remarkable perfection. It was remarkable that, whilst the body contained no alimentary canal, there was lying by it, and quite independent of it, a cylindrical tube, which on being opened poured out a substance like meconium; on microscopical examination this tube presented all the characteristics of a piece of intestine. Of course, development of anything like this extent is rare, the elements found being generally of an epithelial nature, a

fact which the author accounts for by pointing out that the epiblast is the first to appear of the layers, and that in the cases in question development has not proceeded any further. If this view of ovarian dermoids is correct, we ought to find, as indeed we do, teratomata of a similar kind connected with the testis, and owing their origin to a similar parthenogenetic development. The opposite term to such a process of imperfect development would be a redundant evolution, due to over-fecundation, and this the author believes to be the only probable cause of diplogenesis. Following upon the polyspermia would be the apparition of two primitive streaks, which, as is verified by the facts, appear at the edges of the blastodermic disk, may take any position with regard to one another, at right angles, opposite, side by side, &c., and consequent upon their relative position to one another will be the position and amount of fusion of the future double monstrosity. In other cases, he thinks, the ovum may present two blastodermic disks as the result of the presence in it of two germinal vesicles, *i.e.*, of two female pronuclei. Such cases are very rare, almost theoretical, and perhaps only realisable in those vertebrates which, like birds, reptiles, and cartilaginous fishes, have a large vitellus. The present reporter has (XVIII.) described a number of double malformations amongst fishes, and collated the accounts given by previous writers. He finds that there is a regular series of these forms, which may be arranged as follows:—(a) Three eyes of the same size; (b) Three eyes, of which the median is larger than either of the two lateral; (c) Four equal-sized eyes; (d) Duplicity of the head, extending to the otic region; (e) do. to pectoral region; (f) Duplicity extending to the posterior part of the yolk-sac; (g) extending still further back, so as to leave a triangular gap behind the sac; (h) Caudal extremities overlapping, but fused by their contiguous aspects; (i) Caudal extremities united only; (j) Ventral union—*anakatadidymus*; (k) Parasitism. It will be noticed that a union of the cephalic extremities, the hinder parts being double, has never been described. R  he (XIX.) describes the anatomy of a case of *Juniceps*, and says that it is quite impossible that this form of double monster should arise from an incomplete division of a single form which has made some progress along the path of development. If the division is that of an originally single anlage, then it must take place before the formation of the primitive streak, since this must have been double, and its duplicity must have been due to the formation of two centres of division. Meola and Bakunin (XX.) describe a case of *diprosopus triophthalmus*, the central orbit containing two eyes. The hinder part of the 4th ventricle and the brain around was single, becoming double further forward. The pons was absent, and the cerebella were rudimentarily developed. Those cranial nerves which were destined for the supply of the duplicate area were doubled, the rest single. Thus there were three oculo motores, but four abducentes, two faciales, each with double temporo- and cervico-facial branches. The heart was small, and had an interventricular communication. The arteries were double for the duplicate parts, like the nerves. Fusari (XXI.) describes a case of *dicephalus* in which there were single abdominal and thoracic cavities with one

sternum. There were two heads, necks, upper and lower extremities, and vertebral columns, with a trace of an intermediate thoracic girdle. There was a single heart, with four auricular appendices, two auricles, and two ventricles. There were four lungs. The alimentary canal was double as low as the end of the duodenum, from which point it remained single. The liver was large, and possessed two gall-bladders. Marchand gives a full account of the anatomy of a *Pygopagus* (XXII.), the principal noteworthy points in connection with which are as follows:—(a) The sacrum, from the 2nd vertebra downwards, and the coccyx are double, but these two parts do not belong to one of the two bodies, but are common to both. (b) The lower part of the medullary canal is also common to both bodies. (c) The right end twig of the aorta of the one foetus does not form an umbilical artery, but passes into the left-end twig of the aorta of the other. The cardinal veins of the first foetus are in direct connection with those of the other. (d) There are two rectal tubes, but only one anus, which is common to both. Besides this, there is a second blind anal groove. (e) The vestibulum vaginarum is single, the clitoris with the labia minora shows traces of an originally double origin, and the remaining urinary and genital organs are completely double. (f) The placenta and that part of the umbilical cord which is nearest to it are single, but the remainder of the cord and the umbilici are doubled. Dulong (XXIII.) describes a pair of male foetuses united by their anterior aspects, and possessing a common heart and liver. The anus was imperforate on both sides. Each had a harelip and cleft-palate, so arranged that one looked like the picture of the other in a glass. Two of the upper extremities were normal, but the others were deformed, and possessed each four short fingers. In a case of thoracopagus twins described by Kempe (XXIV.) the heart had six chambers, viz., four auricles and two ventricles, and there was transposition of the viscera in the left child. Parsons (XXV.) describes a most remarkable case of a parasitic foetus attached to an anencephalous autosite. There were three arms, of which the posterior of the left side is double in its lower part, there being traces of two olecrana (*cf.* Dwight's case 5, that of Jolly 6), and the hand was double. The posterior of the two left lower extremities was also partly double, having two sets of tarsal bones, united internally, but distinct externally. These were, no doubt, the extremities of a second foetus, the body of which was welded with that of the autosite.

Kreutzmann (XXVI.) describes a case of *Epignathus*, where a tumour depended from the hard palate of the autosite. This had an alveolar and palatine cleft, through which the stalk of the tumour passed to be united with the vomer and basis cranii. The tumour, which was of the size of a fist, consisted of two parts, and was covered for the most part with hair. At one point was an imperfectly developed set of external female genitalia, possessing labia majora and minora, and a tube representing the vagina. These lay between two rudimentary lower extremities. The tumour was cystic in its nature, and inclosed masses of fat and a cartilaginous mass which may have represented a pelvis. On microscopic examination the stroma was found to consist of a connective tissue, which was very rich in cells.

Scattered through this were strands of unstriped muscular tissue and acinose glands. The cysts themselves were lined with epithelium, which was in some cases columnar, in others flat in its nature. Another case of the same kind is given by Sangalli (XXVII.). The autosite was female, and from its mouth depended a voluminous body, which extended as low as the umbilicus, and consisted of a number of larger and smaller nodules. It hung by two short bands of fibrous tissue from the hard palate. The mass itself was for the most part composed of connective tissue, containing epithelial rudiments. Laminae of bone and bundles of muscular fibres were also found in places.

Sangalli (XXVIII.) describes a case of *Diphallus*, seen first in the living subject, and afterwards more fully examined at a post-mortem examination. The pelvis was large, and the anterior part was wanting. From immediately below this hung down a sac, which was subsequently discovered to have contained a loop of the ileum. There was a penis on either side of the abdomen, and to the outer side of each was a swelling which contained a testis. The right penis was imperforate, and below it was a small opening from which urine was voided. Below this again, and on the anterior aspect, was a false anal opening, the true one being occluded. The left penis was perforate, but the passage ended blindly after a distance of 12 cm. Once a month a thin serous fluid was said to have been voided from this. There were two small urinary bladders, connected with each other by a short transverse passage. Into these the ureters opened, and the urine was voided through the opening under the right penis. Ballantyne and Scot Skirving (XXIX.) narrate another case of this class. The scrotum was divided into two distinct lateral parts by a deep mesial groove, the two sides merged more or less in front, but posteriorly were widely separated, so that at their termination they projected backwards as two distinct pouches, each of which contained a testicle. In front of the posterior end of the divided scrotum, and in the middle line, was an ill-defined swelling, covered with normal skin. From either side of this projected a penis with a very short prepuce; each had a meatus, but it was probable that the urethra of the left side was blind. Between the anuses and the base of the penes-carrying tumour was a granulation-like mass, erectile in its nature, from the centre of which urine was voided as well as from the right meatus urinarius. The literature of the subject of diphallus is carefully dealt with in this paper, and the following conclusions are reached as to this rare condition:—(a) Only about twenty cases exist in the literature of teratology. (b) It does not, *per se*, interfere with intra- or extra-uterine life. (c) Urine may be passed by one or both or neither penes. In the last-mentioned case it is voided from an aperture in the perineum. Semen may be passed in the same way, but in most cases sterility has been the rule, even if there has not been inability to perform coitus. (d) All degrees of duplication have been met with, from a fissure of the glans penis to two distinct penes inserted at some distance from each other in the inguinal regions. (e) The two penes are usually somewhat defective as regards prepuce, urethra, &c.; they may lie side by side, or more rarely may be situated

antero-posteriorly; they may be equal in size, or, less commonly, one is distinctly larger than the other; and one or both may be perforate or imperforate. (*f*) The scrotum may be normal or split; the testicles, commonly two in number, may be normal or atrophic, descended or undescended; the prostate may be normal or imperfectly developed, as may also the vasa deferentia and vesiculæ seminales. (*g*) The commonly associated defects are, more or less completely separated bladder, atresia ani, or more rarely double anus, double urethra, increased breadth of the bony pelvis, with defect of the symphysis pubis, and possibly duplication of the lower end of the spine, and hernia of some of the abdominal contents into a perineal pouch. Much more rarely, duplication of the heart, lungs, stomach, and kidneys has been noted, and the lower limbs may be shorter than normal.

Chiarleoni narrates a parallel case occurring in the opposite sex (XXX.), a child of 33 months. There were two sets of external genitalia, each possessing labia minora, and on the left side a clitoris, which organ was absent on the right. On the left side there was a vestibule about 1 cm. in depth, and a minute opening below the clitoris, from which escaped urine and fæces. In the right vestibule was an opening of a similar character. There was no anus.

HEAD AND NECK.—Valenti (XXXI.) describes a case of *Cyclopia*, in which there were two palpebral openings, but only one orbit and no proboscis. There was a median alveolar cleft, and the right pinna was much altered in shape. The right temporal bone had no tympanic bone, nor trace of external auditory meatus, membrana tympani, nor zygomatic apophysis. There were no ossicles present on this side. A dissection of the orbit showed the existence of one atrophic eyeball, without cornea or lens. The brain had a small single portion representing the cerebrum, with a prominence corresponding to the position of the infundibulum and site of attachment of the optic nerves. The left hemisphere of the cerebellum was smaller than the right. Taruffi (XXXII.) narrates a case of cyclops which is almost if not quite unique, where there were two proboscides, one placed below an orbit containing two eyeballs and the other above it. Broom (XXXIII.) describes another case of the same condition in which there was no mesial eye, but three eyelids which formed a triangle, in the centre of which was an epidermal structure. There was no proboscis. There was an imperfect orbit, posterior to which in the cranium was a median ridge of adipose tissue, containing muscular bundles which represented the ocular muscles. Into this passed the usual nerves of the orbit. There was no pineal body, nor anterior corpora quadrigemina, cerebrum, or olfactory lobes. The author thinks that the primitive characters preserved in cyclopians form a link between the Craniota and the Acrania. In the head described are present all the primitive vertebrate structures, but there is a complete absence of most of those peculiar to the Craniota. He does not think that the failure in development could have been produced by an occlusion of blood-vessels, since the ground-plan must have been laid down before any blood-vessels were formed; and the only conclusion which seems tenable is, that there has been some alteration of the potentiality of the developing cells of the ovum, so

that they have completed their evolution when they reached the stage corresponding to the adult development of the remote ancestor.

Frau v. Leonowa-Moskau (XXXIV.), in speaking of the condition of the sense organs and ganglia in *Anencephalus*, says that a consideration of the facts which she has already brought forward, together with those mentioned in this paper, shows that (a) the development of the sensory nerve system is independent of the medullary tube; (b) that the peripheral sensory fibres, like the posterior nerve-roots, grow out of the spinal ganglia, as His teaches, and as also follows from the teachings of the school of Gudden, that they must be considered as the nuclei of origin of these fibres. The existence of the Gasserian ganglion and of the ganglion nodosum also shows that these structures are the sensory ganglia of the Vth and Xth nerves, which also show a similar independence of the medullary tube to that of the spinal ganglia and the posterior nerve-roots. It is worthy of mention that the voluntary musculature of the foetus in question presented no deviations from the normal, although there were no motor nerve fibres present, and no spinal cord.

Schulte, in an inaugural dissertation (XXXV.), gives a careful account of the bones of the basis cranii in cases of anencephalus, together with a collection of cases which seem to show that the condition has its origin in a foetal hydrops. Manouvrier (XXXVI.) describes a case of microcephaly in a living child, which presented also unusual development of the canines and a single transverse palmar fold only, which are pithecoïd characters. The origin of the malformation is referred by the mother to the fact that during her pregnancy she was in the habit of carrying heavy loads of wood, which she rested against the front of her abdomen.

Barwell (XXXVII.) describes the case of a young female who possessed a median *Cervical Fistula*, situated on the most prominent part of the thyroid cartilage, which occasionally discharged a little thin fluid. The small orifice was surrounded by depressed and reddened skin for about a quarter of an inch from side to side; nearly half an inch from above down it was partially overhung by a transverse narrow fold of healthy skin. On palpation a line of cylindrical, somewhat hard tissue could be felt running up from the opening to the hyoid; this seemed to be about the size of a cedar pencil. The foramen cæcum was not abnormally large. The author diagnosed the condition as a tubular remnant of a supra-hyoid accessory thyroid gland. Ballantyne gives an account of the chief facts known about preauricular appendages (XXXVIII.), which he believes to be produced by a budding from the margins of one or other of the fissures between the facial processes, produced by the agency of amniotic adhesions. Titone (XXXIX.) gives a minute description of the anomalous arrangement of the fissures and convolutions of a human brain.

HEART.—Griffith (XL.) describes the heart of a child which survived its birth for eleven weeks. There was a widely patent foramen ovale, also an aperture through the septum ventriculorum at the anterior part of the undefended spot. There was also a lateral and, which is much rarer, an antero-posterior transposition of the aorta and the pulmonary artery.

ABDOMEN.—Tesson (XLI.) describes a case of fusion of the *Kidneys*, in which the renal mass taken as a whole has the form of an L open towards the right (┐), or, in other words, it is formed of two branches, one of which is vertical and directed towards the left, the other horizontal and directed towards the right. The horizontal portion lay in front of the lumbar portion of the vertebral column, covering the aorta, the vena cava inferior, and the branches at the bifurcation of these vessels. The vertical portion presented, not at one of its edges, but on its anterior aspect, a hilus, from which arose a ureter. Dwight (XLII.) describes a case of anus vulvalis. The rectum opened into the vestibule just above the posterior commissure; its calibre was smaller than usual, and there was no apparent sphincter. There was a very slight hymen. Pilliet and Bouglé narrate (XLIII.) a remarkable case of duplicity of the uterus of a very unusual type. On the right side was a vagina, a cervix uteri leading to a uterine cavity, the organ itself being fibromatous. On the left side there was no kidney or ureter, though the suprarenal was present; but there was an elongated uterus, provided with two cornua, and resembling in its form the foetal type. It possessed at least one ovary, and was plastered up against the wall of the iliac fossa and of the true pelvis. It did not communicate with the other uterus. The authors think that two hypotheses might be put forward to account for this condition of affairs. It might be a case of true duplicity of the uterus, one of the two at least (the right) resulting from the fusion of the two Mullerian ducts; one not developed, the other fibromatous. Or, secondly, considering that four ovaries were not discovered, it might be argued that some unknown cause had suppressed the left kidney and ureter and divided the uterus at the level of the pelvis, leaving the upper part infantile, and the lower developed. Griffon (XLIV.) gives an instance of the ordinary type of bifid uterus, the peculiar feature in connection with which was the existence of a partition passing antero-posteriorly so as to divide the pouch of Douglas into two lateral compartments. This partition was formed of two layers of peritoneum. Jacques (XLV.) describes an interesting case of *Uterus Masculinus*. The subject from which it was taken had normal external genitalia, and two normal-sized testicles lay in their ordinary position in the scrotum. Above the prostate, and between the vesiculæ seminales, was an elongated, prominent body, as large as a finger at its upper part. It was slightly flattened from before backwards, and was muscular in structure. Its cavity was continuous with the prostatic sinus, and the mucous membrane which lined it presented a number of small blind depressions, very similar in appearance to the lacunæ of the urethra. On microscopical examination a great number of epithelial cavities were seen which occupied the wall of the abnormal organ and communicated with its interior. The author thinks that the organ described cannot be compared morphologically with the uterus, and still less with the entire utero-vaginal canal, whether its macro- or micro-scopic characters are considered. The character of the epithelium is neither that of the vagina nor of the uterus, and there is no trace of any segmentation into two superimposed parts. From the morphological point of view, he thinks that

the cavity of the organ should be looked upon as a diverticulum of the prostatic urethra, lined by a mucous membrane very analogous to that of the urethra. Targett (XLVI.) records two cases of *Pseudo-hermaphroditism*: (a) passed as female, had a marked hypertrophy of the clitoris, with altered sexual inclinations; (b) passed as male, though originally thought to be a girl, and named as such. The general appearance and disposition of the subject were those of a male, but the appearance of the genitalia was that of an immature female, with the exception of the clitoris, which resembles the penis of a hypospadiac male. A swelling in this subject in the right labium is regarded by the author as having probably been an ovarian hernia. Cole (XLVII.) gives an account of a case of hermaphroditism in the frog. The left genital gland or ovo-testis contained a single very degenerate ovum. Its capsule proved to be a seminiferous tubule, which at one end contained a number of spermatozoa. For the most part this gland was made up of a mass of polygonal pigment cells which occur normally in the frog's ovary, with however patches of normal testis at its poles. The right gland or testis was somewhat larger than normal, was a normal mature testis, and contained one ovum. Bauer describes a case of anterior abdominal fissure (XLVIII.) commencing just below the sternum. There was also lordosis of the vertebral column, right scoliosis, and spina bifida.

LIMBS.—Manners-Smith, in a paper (XLIX.) on two specimens of *Symmelia* which he has dissected, gives a list of the chief abnormalities of the muscular and osseous systems which have been met with in this class of monstrosities. He thinks that the theory of S. Hillaire, interpreted in the light of modern biological research, is the one which is most satisfactory, viz., that there is an inherent tendency for the side plates or limb buds to unite, an affinity of like part for like part,—understanding by affinity nothing more than a greater tendency for similar than dissimilar parts to fuse. That this tendency is latent, and is comparable to, and is possibly the descendant of, that fusion which (adopting the most recent view as to the origin of paired and unpaired limbs) takes place in the posterior portion of the fin elements of certain fishes. Krakenberger (L.) describes an instance of *Macroductyly* affecting the fingers of both hands. The right hand was much enlarged, and the three central fingers particularly so, the pollex and minimus being only to a slight extent increased in size. The left had very much hypertrophied annularis and medius, and these fingers were also united in the same sheath of skin, though they possessed separate nails and bones. The last-mentioned fingers were removed when it was found that there was a great deal of fat under the skin on the volar surface. In connection with the bones, the great enlargement of the epiphyses was specially noticed, these being covered by numerous exostoses. The size of the diaphyses was fairly normal. A microscopic examination showed a very unusual amount of vascularity of all the tissues. Galvani (LI.) narrates two cases of *Congenital Hypertrophy*: (a) male, æt. 25, no family history of abnormalities: he was born with an enlargement of the right hand and forearm, but a very remarkable relative increase took place after the age of 20: after amputation it was noticed that the muscles and

bones were normal in their size, that the subcutaneous veins were dilated, and that the enlargement was due to the adipose and other subcutaneous tissues; (b) Child æt. 11 months, no family history of abnormalities: at birth the left foot was larger than normal, and the second phalanx of the great toe was nearly double its proper size, the other toes were of the ordinary size: this condition had greatly increased since birth.

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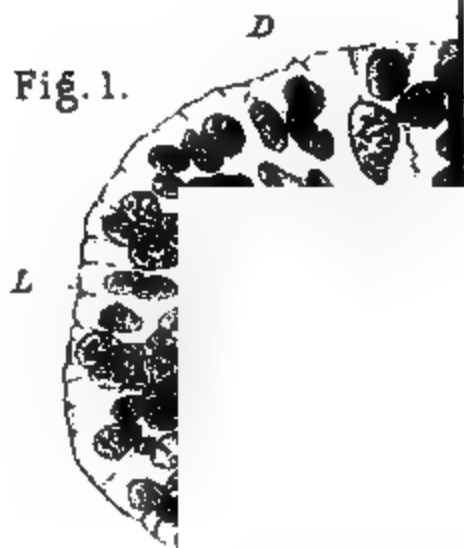
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Fig. 1.



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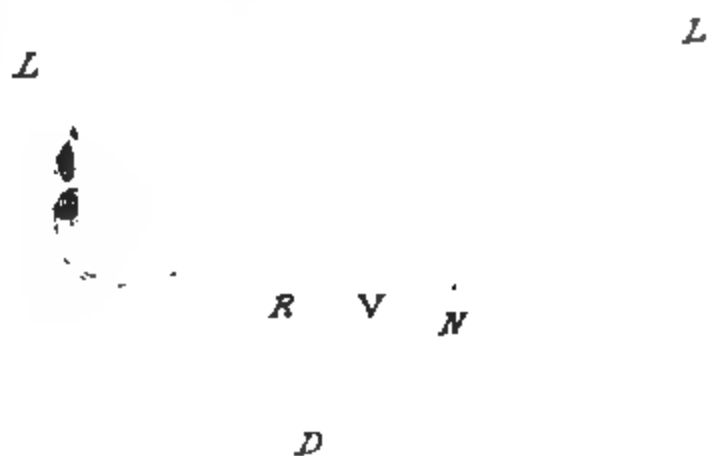


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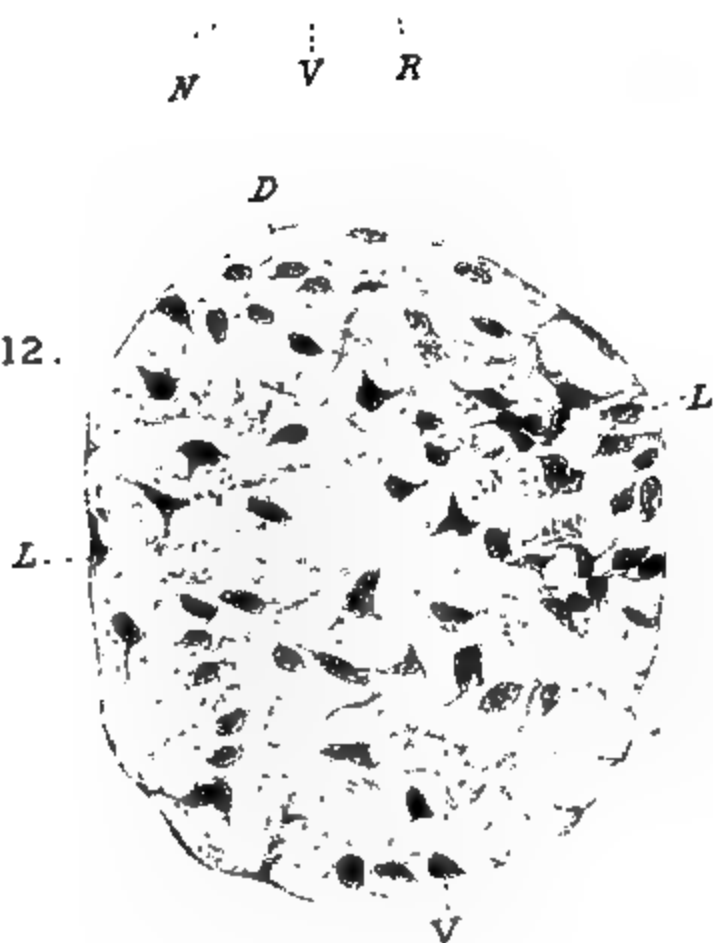
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Fig. 12.



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Journal of Anatomy and Physiology.

THE STRUCTURE OF THE CEREBRAL HEMISPHERE OF *ORNITHORHYNCHUS*. By G. ELLIOT SMITH, M.D., Ch.M., *University of Sydney*.

IN a preliminary paper concerning the anatomy of that part of the hemisphere which surrounds the hilum, which was recently published in this *Journal* (1), I advanced certain views, which are more or less at variance with the currently accepted theories of cerebral morphology. As these conclusions were the direct outcome of a somewhat extended comparative study of the brain of *Ornithorhynchus*, I propose, before further discussing the questions raised in the preliminary paper, to give a brief account of some of the outstanding features in the morphology of the hemisphere of *Platypus*. For the sake of brevity and conciseness, I shall postpone the description of the histology, only referring to the minute structure in as far as it has a direct bearing upon morphology. At the same time it is only right to mention that all the statements made here are based upon an extensive and comparative histological study.

The early literature of the subject, which is comprised in the works of Meckel (2) and Owen (3) and the brief note by Garner (4), has been so frequently and fully reviewed (Flower (5), Symington (6), Hill (7), among others), that it is quite unnecessary to do so here.

In 1891 Sir William Turner published (8) a brief account of the surface anatomy, which he has just supplemented by a short paper and figure (9) in this *Journal*. Johnson Symington in 1893 contributed a note and figure relating to the commissures only (6). The most ambitious attempt to describe the cerebrum of *Ornithorhynchus* is the paper which Alexander Hill presented to the Royal Society of London in 1892 (10).

The only other reference to any original work upon the Platypus brain (apart from the numerous short notes (11) which I have published during the past eighteen months) is the reference made by Zuckerkandl in his monograph on the smell centre (12). His material was apparently in such bad condition that his figures and description are valueless.

I have had the immense advantage, which all previous workers have lacked, of abundant fresh and properly preserved material with which to work. This enables one to speak definitely and without hesitation upon many features, which previous workers, from the nature of their material, have been obliged to neglect altogether, or to speak of in a very undecided manner. The monotreme type constitutes an extremely important stage in the evolution of the mammalian cerebrum. For wide as is the gap which separates the Prototheria from reptiles, the hemisphere of *Ornithorhynchus* in certain features presents a much stronger resemblance to the reptilian than to the Eutherian structure.

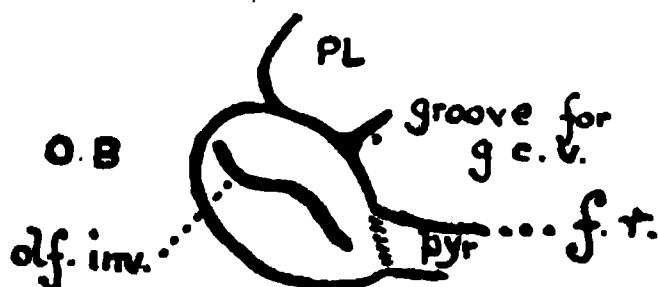
In addition to the interest and importance which attaches to the brain of *Ornithorhynchus* from the zoological position of its possessor and its transitional characters, it presents a number of features of an individual interest to the neurologist. Of these the most important is perhaps the enormous development of the trigeminal nerve, which is peripherally connected with numerous specialised sense organs, which have been described by Wilson and Martin (13). Associated with this great development the pons and medulla present upon their ventral aspect a huge swelling, due to the large size of the so-called sensory nucleus of the fifth nerve. The substantia gelatinosa Rolando in the medulla and cervical cord also attains very large proportions. Associated with these features there is a huge fillet, ending in the optic thalamus of the opposite side. The thalamus attains very large dimensions, and presents an extreme degree of lateral extension, reducing the corpus striatum posteriorly to a mere film of grey matter (*vide infra*, sch. 5 and 10).

Arising from this thalamus there is an extremely abundant fibre system, which contributes as much to the internal capsule as the crus cerebri does.

The olfactory bulb consists of a small ellipsoidal grey mass

lying in front of, and partly overlapped by, the hemisphere proper (sch. 1, 2, 3, and fig. 12, *o.b.*). Its peculiar features I have already described and figured (14). Briefly it may be described as a thin walled sac, which has become deeply invaginated along an oblique line situated upon the upper part of its lateral wall (schema 1, *olf. inv.*).

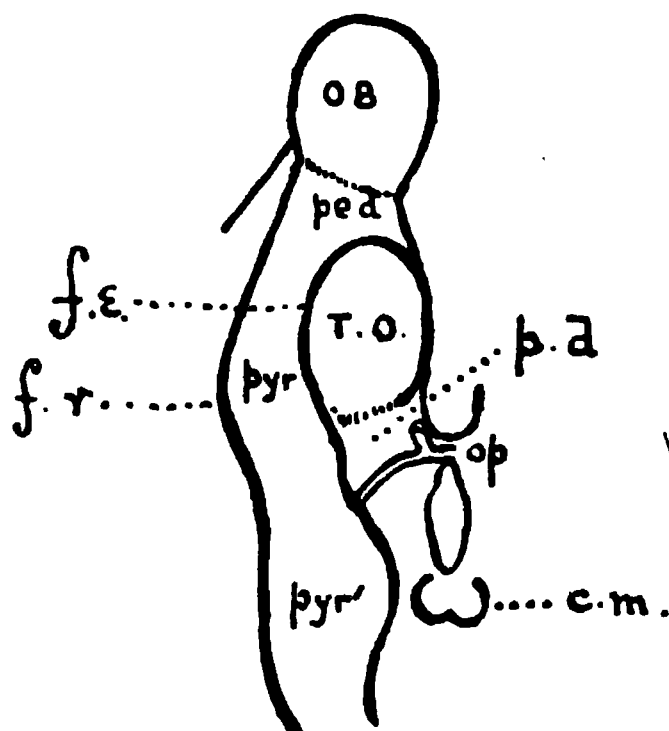
While the general morphology of the bulb in *Ornithorhynchus* conforms to the reptilian and that of *Echidna* to the mammalian



SCH. 1.—Lateral aspect—olfactory bulb $\times 2$.

type, the organ in both monotremes probably diverges widely from the early Prototherian type. In its fine structure, as exhibited by the Golgi-stain, it resembles that of other lowly mammals.

The bulb is connected to the hemisphere proper by means of a short peduncle, which presents an elliptical outline in trans-



SCH. 2.—Ventral aspect of the anterior part of hemisphere $\times 2$.

verse section, the major axis being transverse. The walls of its lumen, lined with low columnar epithelium, are concentric with its peripheral outline. Upon examining the basal aspect (fig. 12 (p. 487) sch. 2) of the brain, the peduncle (*ped.*) will appear to divide

into two parts, which are separated by a slight boss of grey matter of elliptical outline—the *tuberculum olfactorium* (*t.o.*). The lateral division of this apparent backward extension of the olfactory peduncle is the *pyriform lobe* (*pyr.*), which forms a narrow and somewhat irregular band of grey matter, extending backwards to end eventually by turning upwards upon the mesial hemisphere wall behind the hippocampus. (This has been described and figured in this *Journal*, vol. xxx. p. 159, fig. 1.)

This pyriform lobe is limited laterally by a deep and very well defined *rhinal* (*ectorhinal*) *fissure* (*f.r.*), which separates it from the *pallium* (using that term in Turner's sense).

Behind the prominence of the tuberculum olfactorium there is a pale depressed area (*sch. 1, p.d.*), which is directly continuous (above the optic chiasma) with the floor of the 'tween-brain. The homologue of this region in the cat has been distinguished by Burt Wilder (15) as the *portio depressa*, in contradistinction to the tuberculum olfactorium, which he calls *portio prominens* of the *locus præperforatus*. It corresponds to the basal part of the *gyrus subcallosus* of Zuckerkandl (the *pedunculus corporis callosi* of Vicq-d'Azyr; the *pedunculus septi pellucidi* of Burdach). This region, which may be called the *area depressa*, corresponds to the true anterior perforated space, where the small basal vessels enter the corpus striatum. Ganser has clearly pointed this out in the brain of the mole, in which he distinguishes this region as the *substantia cinerea anterior* of Stieda (16). It is a curious fact, however, in the monotremes that the lenticulo-striate vessels enter the ganglia in the depths of the fissure (*endorhinal*) which separates the tuberculum olfactorium from the pyriform lobe.

In *Platypus* this fissure also extends backwards, cutting off the *area depressa* from the pyriform lobe. In *Echidna* and all other mammals the *area depressa* is directly continuous with the pyriform behind the *fissura endorhinalis*.

The region of the mesial hemisphere wall in front of the commissures has hitherto only been very imperfectly understood, in spite of the numerous and detailed descriptions which have been published concerning it in various animals. The detailed accounts of its development in higher mammals (by His, Marchand, and Paul Martin, among others) have failed to throw the

necessary light upon the subject of its morphology. But the intrinsic difficulties in the interpretation of its morphology in the higher mammals are so great as to be practically insuperable without the key which the monotreme or marsupial affords. Direct comparison of Eutherian with reptile is only likely, from the very simplicity of the latter, to aggravate the difficulty and increase the confusion. The two main factors in the evolution from reptile to Eutherian—and hence the causes of the confusion—are (1st) the disappearance of the cephalic extremity of the hippocampus, and (2nd) the encroachment of the pallium,—both signs of a higher type of cerebrum. In the monotreme and marsupial one finds at the same time all the stages in the encroachment of the pallium, without, however, the loss of the anterior end of the hippocampus. Hence there is provided a complete series of stages from submammalia to Eutheria, which show at a glance the meaning of the arrangement. It would be difficult to exaggerate the importance which the bearing of these facts has upon the interpretation, not only of the region in question, but of the entire hemisphere in the whole vertebrate series, the essential uniformity of whose general plan it so clearly demonstrates—in contradistinction to the manifest want of uniformity which must have impressed anyone who has examined the literature of this subject.

Upon glancing at this region of the hemisphere in *Ornithorhynchus*, the mesial wall of the olfactory peduncle (sch. 3, *ped.*) will be seen to extend upwards and backwards above the tuberculum olfactorium (*t.o.*), which appears as a fusiform grey mass, to become continuous with a region which shall presently be described as the 'precommissural area.'

The thin *lamina cinerea* (*l.c.*) will be seen extending upwards from the optic chiasma (*op.*) towards the *commissura ventralis* (C.V.). Here the lamina terminalis, of which the lamina cinerea forms the ventral part, swells out to include not only the *commissura ventralis*, but also the *commissura dorsalis* (C.D.). Included between these two great commissural bands there is the thickened lamina terminalis (S.) which I have elsewhere (17) called the *commissure-bed*. It consists of a bridge of grey matter connecting the precommissural area of one hemisphere with the other. When it becomes stretched and otherwise

The *precommissural area* (P.A.) is clearly distinguishable from the surrounding regions by its much paler colour, which is caused by a dense network of nerve-fibres which are situated immediately below its surface (*vide infra*, sch. 11 and 7). Hence it may be readily mapped out in a fresh brain, in a manner which is represented in schema 3.

Dorsally it is separated from the pallium by the hippocampus, of which the fascia dentata (F.D.) appears upon the surface. But below and in front of these structures the precommissural area and the mesial surface of the olfactory peduncle both become continuous with the pallium. The dividing line between these regions and the pallium is clearly seen in the fresh brain from their paler colour (*vide* sch. 11), but it is also indicated by a shallow furrow (sch. 3, β), which conducts a vein from the hippocampal fissure (*h.f.*) to the groove between olfactory peduncle and pallium.

It was to this area of blending of olfactory peduncle, precommissural area, and pallium in the Eutherian brain that Broca gave the name *carrefour de l'hémisphère* (18). Since his time this heterogeneous field has been adopted as a definite cortical region, under the name *Broca's area* (19), or as the *area par-olfactoria* of His (20). From what has just been said regarding its constitution, its value as a morphological division of the cerebral surface is very questionable. The want of definiteness about the limits of the region plainly shows itself in the descriptions given by different writers. As figured and described by Broca (*loc. cit.*) it is mainly composed of precommissural area, whereas it is largely composed of pallium as His describes it (*loc. cit.*).¹

THE HIPPOCAMPUS.

All that can be seen of the hippocampal formation in a view of the undisturbed mesial wall of the hemisphere is the small fusiform area (sch. 3, *f.d.*) above the dorsal commissure, which corresponds to the anterior extremity of the fascia dentata. This is limited above by the hippocampal fissure. The fascia dentata may be seen in the rest of its extent by drawing aside in a fresh brain the pallial operculum, which extends downwards

¹ Since this was written, Edinger has used the term (in speaking of the reptile-brain) in quite a new sense.

and hides the posterior part of the hippocampal formation from view.

If the lateral ventricle be opened up and the corpus striatum and overlying cortex be removed, the hippocampus may be seen as a prominent bulging from the inner wall of the ventricle. The outline of this bulging is roughly represented (twice the natural size) in sch. 4. From this it will be seen that the posterior extremity rapidly tapers as it bends downwards and forwards as a long diminutive tail.¹ Anteriorly the hippocampus also tapers slightly as it bends downwards and forwards round the precommissural area.

The tail of the hippocampus retains to its extremity the typical structure, and bulges into a long narrow descending horn



SCH. 4.—The hippocampus (in silhouette) seen from the ventricular aspect. The precommissural area and anterior commissure in outline $\times 2$.

of the ventricle, of correspondingly diminutive proportions. Although the hippocampus of *Echidna* possesses a tapering posterior extremity, it cannot be compared to the peculiar appearance which that of *Ornithorhynchus* presents.

In a horizontal section made through the upper part of the commissura ventralis, the extreme anterior end of the hippocampus and the 'tail' will be both cut transversely. The appearance of such a section is represented in schema 5, and the two hippocampal regions are shown on an enlarged scale in the schemata 5' and 5".

The anterior extremity of the hippocampus will be seen (sch.

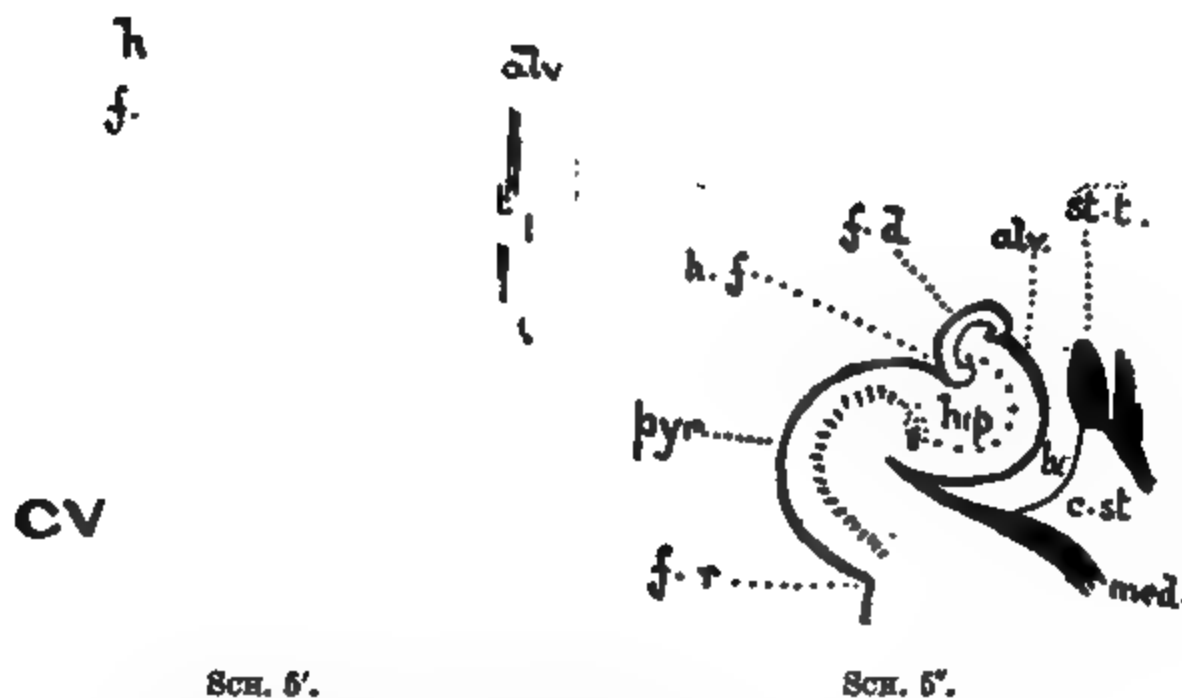
¹ In this *Journal* in October last I described and figured the hippocampus with a considerably shorter 'tail.' In all my earlier specimens the extremely delicate extremity of the hippocampus had become lost in the process of hardening. It was only quite recently, in dissecting some fresh material, that I discovered its true extent.

h. f.
 f. d.
 p. a.
 c. v.

p. d.

f

SCH. 5.



SCH. 5.—Horizontal section through the forebrain at the level of the upper part of the anterior commissure (c.v.). \times about 3.

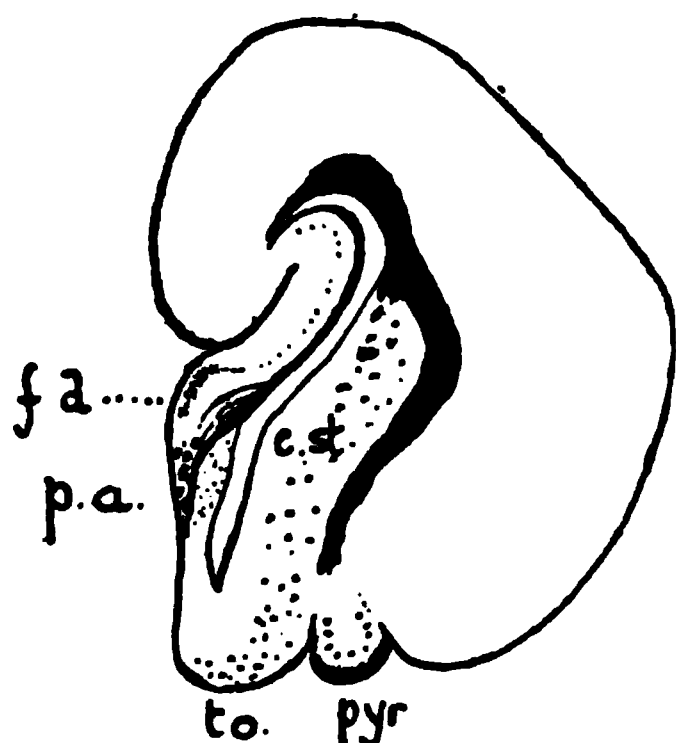
SCH. 5'.—The anterior part of the hippocampus from Sch. 5 enlarged.

SCH. 5''.—The "tail" of the hippocampus from Sch. 5 on a larger scale.

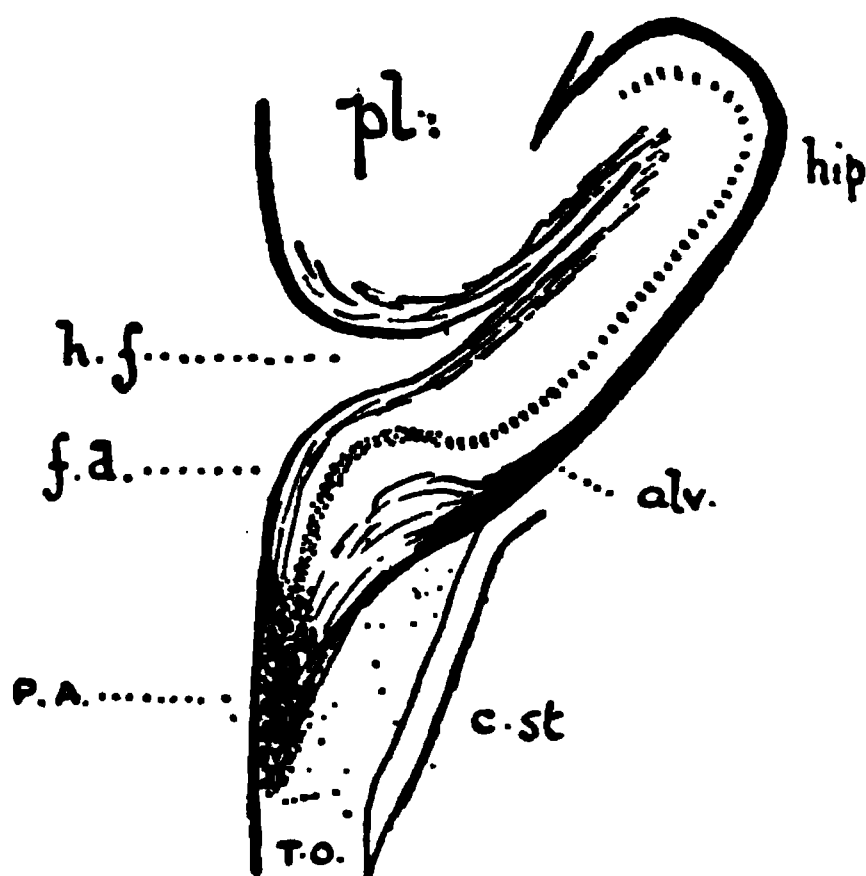
5') as a slight bulging (covered with alveus fibres, *alv.*) into the anterior horn of the ventricle. The fascia dentata (*f.d.*) lies on the surface immediately behind the hippocampal fissure (*h.f.*); and the whole formation is separated from the commissura ventralis by the precommissural area, the surface of which is white from the presence of large masses of nerve fibres in its superficial part, but whose ventricular aspect is grey, and therefore contrasting markedly with the white covering of the pes hippocampi.

Coronal sections through the anterior extremity of the hippocampus are represented in schemata 6 and 7 (*vide infra*).

The horizontal section through the 'tail' of the hippocampus presents a very different appearance (sch. 5"). The small hippocampus (*hip.*) with a very thin alveus (*alv.*) and no fimbria



SCH. 6.—T.S. in front of the commissures.



SCH. 7.—T.S. anterior extremity of hippocampus and precommissural area.

bulges into the little crescentic cavity of the descending horn of the ventricle (*l.v.*). Its margin is capped by the fascia dentata.

Immediately behind the hippocampus is the upturned posterior extremity of the pyriform lobe (*pyr.*), limited anteriorly by the hippocampal fissure (*h.f.*), and posteriorly by the rhinal fissure (*f.r.*).

This is the part of the pyriform which is the homologue of the gyrus hippocampi (uncinatus).

In a transverse section through the anterior extremity of the precommissural area, the mutual relations of a number of distinct histological formations is demonstrated (sch. 6 and 7). Thus the fascia dentata (stratum granulosum and stratum moleculare) and the 'nucleus fasciæ dentatæ' (i.e., the mass of polymorphous cells lying between the stratum granulosum and the ventricle) will be seen to form the ventral margin of the hippocampus and to fuse with the *precommissural area* (*p.a.*).

Upon looking into the ventricle of the fresh brain in the region indicated in sch. 6, the floor and lower parts of the lateral walls will be noticed to be formed by an apparently uniform grey mass, which contrasts markedly with the white roof and upper parts of the lateral walls. This grey mass is formed by the *precommissural area* (and its backward continuation—the *commissure-bed*), which becomes continuous (sch. 6) in the floor of the ventricle with the corpus striatum (*c.st.*), which here forms the greater part of the lateral wall of the ventricle.

In this region the corpus striatum will be observed to extend down to the base of the brain without any apparent line of demarcation between it and the surface region called 'tuberculum olfactorium.' In the marsupials and most Eutheria the tuberculum olfactorium has a well defined cortex, which Ganser has well described in the mole under the name 'Rinde am Kopf des Streifenhügels' (21). In *Ornithorhynchus* (like the reptiles) no definite cortical arrangement is discernible, but merely a scattered mass of cells not definitely marked off from the corpus striatum. This fact led Adolf Meyer (who worked at the reptile brain) to make the erroneous generalisation that this region is cortexless, and a place where the central ganglia come to the surface of the brain (22). The cortical area which does exist appears to be purely olfactory in function. Fibres from the olfactory radiations terminate in it; it varies in size with the degrees of macrosmatism; and it appears to be absent in the anosmatic cetacea (I have examined the porpoise).

The precommissural area also varies in development with the olfactory apparatus, of which it appears to be a 'switch-station' between olfactory bulb and hippocampus. It also appears to be quite wanting in the porpoise, the large bare area where the corpus striatum comes to the surface on the basal and mesial

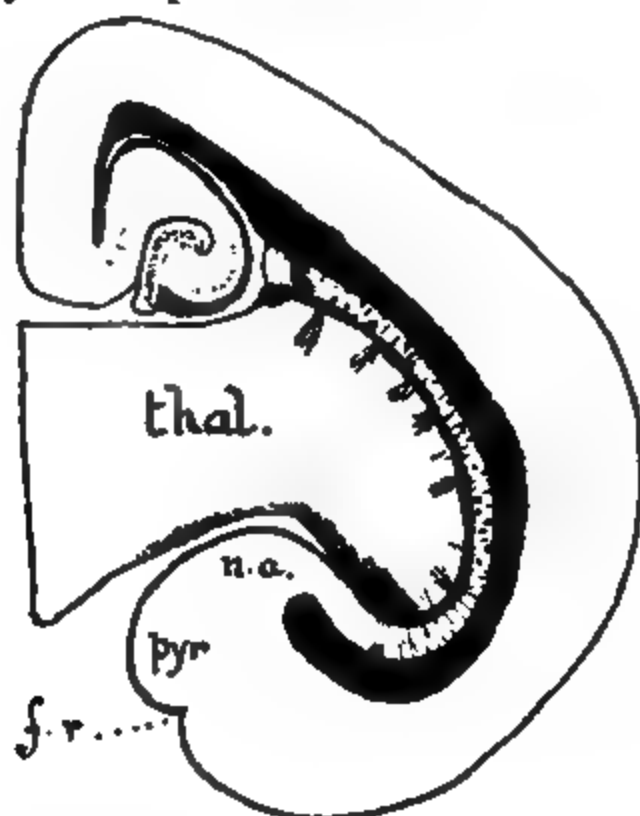
Perameles, *Talpa*, *Erinaceus*), with much smaller pallia, have relatively larger and much better developed internal capsules. It

f. d.
s. med.
thal
med
c. v...

J. d. f. r.

SON. 9.—T.S. just behind the commissures.

is undoubtedly an important transitional feature between the



SON. 10.—T.S. posterior part of hemisphere.

discrete peduncular system of the reptilia and the concrete internal capsule of higher mammals.

Certain Fibre-tracts of the Cerebrum.

The fibres arising from the mitral cells of the olfactory bulb—the so-called ‘olfactory radiations’ (Riechstrahlungen) of Edinger—proceed backwards upon the ventral, lateral and mesial surfaces of the olfactory peduncle. They have been divided by various writers into a number of ‘roots’ or ‘tracts,’ which have been distinguished by names which are utterly perplexing, not so much from their variety—for they are singularly limited in number—but from the varied significance attached by

SCH. 11.—Showing the most important fibre tracts in the mesial hemisphere wall.

different writers to practically the same name. I shall therefore be content to describe such tracts as I have found, avoiding this confusion of nomenclature.

1. The most lateral fibres extend directly backwards, to terminate by end-branchings in the molecular layer of the pyriform lobe—*tract to pyriform*.

2. The most internal fibres (sch. 11, b.) extend upwards and backwards upon the mesial wall of the hemisphere, to end in the precommissural area—*tract to precommissural area*.

3. The intermediate fibres extend directly backwards, to ter-

minate in the superficial layer of the cortex of the tuberculum olfactorium—*tract to the tuberculum olfactorium*.

These three tracts form the second stage of the olfactory path, the first stage being formed by fibres arising in the olfactory mucous membrane, and ending in the glomeruli of the olfactory bulb.

Hippocampal Fibres.

Fibres arising from or about to enter the hippocampus cover its ventricular surface, as the so-called *alveus*. The fibres from the alveus collect at its margin, and form a longitudinally running bundle, which in Metatherian and Eutherian brains forms a prominent ridge—the *fimbria*. This ridge is extremely poorly developed in both monotremes, and more especially in *Ornithorhynchus*, in the greater extent of whose hippocampus no sign of a ridge is discernible in transverse section (see sch. 5", 9 and 10).

The fibres from that part of the hippocampus lying behind the lamina terminalis are conducted *via* the fimbria to the region of the commissures, where they behave in varied ways.

In the monotremes and marsupials, however, a considerable part of the hippocampus lies above and in front of the commissural region. How do the fibres from this region behave? Unlike the fibres from the posterior region, all the hippocampal fibres from the anterior region do not enter the lamina terminalis, but proceed more or less directly to their destinations. One therefore has an admirable opportunity, which the Eutherian brain does not afford, of studying the course of these fibres.

Schema 11 represents a sagittal section through the mesial surface of the anterior extremity of the fore-brain. In it, fibres have been drawn (by camera lucida) from a series of sections in various planes, but all within a thickness of less than 1 mm.

The fibres brought from the posterior parts of the hippocampus by the fimbria, enter the lamina terminalis at the situation occupied by the dorsal commissure (*c.d.*). Here a considerable proportion of them cross the middle line, forming this dorsal or hippocampal commissure.

Others bend downwards and backwards behind the ventral

commissure to form part of the *columna fornicis* (*a.f.*). This column also receives contributions from the anterior part of the hippocampus. These fibres may be seen describing a somewhat S-shaped course through the precommissural area and 'septum' above the ventral commissure. Fibres then collect from all parts of the hippocampus to form the column fornicis of the same side. A second series of fibres collected from all parts of the hippocampus extend downwards in front of the commissura ventralis, and arch round in the precommissural area towards the *portio depressa*, where they form part of a very well marked bundle (sch. 11, *a.*), which extends across the *portio depressa* upon the base of the brain, and ends in the region of the nucleus amygdalæ. This definite bundle is the *pedunculus corporis callosi* of Vicq-d'Azyr, the *pedunculus septi pellucidi* of Burdach, the *bandelette diagonale* of Broca, and the main part of Zuckerkandl's 'Riechbündel des Cornu Ammonis' (23). The grey area in which it lies is the *gyrus subcallosus* of Zuckerkandl. It may be remarked in passing that this—the great bulk of the so-called 'Riechbündel'—is probably not associated in any way with the sense of smell. It is merely an association bundle between the hippocampus and the region of the nucleus amygdalæ. I shall therefore distinguish it as the *hippocampo-basal association bundle* of precommissural fibres. As it is present in an extremely well developed form in certain anosmatic cetacea (porpoise), there is good reason to question the propriety of Zuckerkandl's name.

Arising in the precommissural area there is a scattered but important series of fibres (sch. 11, *c.*), which proceed directly upwards and backwards into the fascia dentata (*f.d.*), where they course (and apparently terminate) in the molecular layer (*d.*). I have described this bundle (24) as the *olfactory bundle* of the *fascia dentata*. At that time I was firmly convinced from the appearance of Weigert-stained sagittal sections (*vide* sch. 11) that it was a direct and uninterrupted tract from the olfactory bulb to the fascia dentata (*i.e.*, that the fibres *b.* and *c.* were continuous). The appearance in the sections was deceptively like that of a direct tract. But the appearance of sections of a *Perameles*-brain (stained by Marchi's method), in which an experimental excision of the olfactory bulb was practised, lends no support to the idea of a direct and unbroken tract. While further investiga-

tions by the degeneration method are necessary to settle this point, it seems clear that the *olfactory bundle to the fascia dentata* is interrupted in the precommissural area.

In addition to these tracts, there is a strong fibre connection in the mesial hemisphere wall between the deep aspect of the cortex of the tuberculum olfactorium and the alveus hippocampi.

A few fibres from the precommissural area appear to enter the dorsal commissure, constituting the *commissure of the precommissural area*. Of this more will be said later.

The Commissures.

Fibres derived from the whole extent of the pallium, from the pyriform lobe and nucleus amygdalæ, from the olfactory peduncles and tuberculum olfactorium, collect to form a large strand of fibres—elliptical in sagittal section—which passes through the corpus striatum, gaining fibres from the latter as it goes, to cross the middle line in the lamina terminalis as the *commissura ventralis*.

The fibres derived from the rest of the hemisphere—hippocampus and precommissural area—form the *commissura dorsalis*. In *Ornithorhynchus* the fibres of the dorsal commissure, as they cross the middle line, simply form a loose rounded bundle, with no attempt at any morphological arrangement. In *Echidna* there is little, if any, more definite disposition of fibres. This is another feature in which the monotremes differ from all other mammals, and resemble the submammalia. In the marsupialia one can trace the evolution of the dorsal commissure band from the amorphous monotreme condition to the definite bilaminar commissure of the Macropodidæ, whose illusory resemblance to the whole dorsal commissure of higher mammals so deceived Flower in 1865 (25). Thus the arrangement of the hippocampal commissure in Koala is but a slight advance upon that of the monotreme, while *Perameles* and *Dasyurus* occupy a position intermediate between the stages exhibited by Koala and Macropus. In the evolution of the Eu- from the Metatheria a new and more deeply significant factor comes into play. A bundle of fibres springing from the dorsal part of the pallium, whose undoubted homologues form part of the ventral commis-

sure in the Proto- and Meta-theria, now passes across the middle line with the fibres of the dorsal commissure (26). The latter therefore now consists of three instead of two series of fibres: (1st) the commissural fibres of the precommissural area; and (2nd) the hippocampal commissure, both of which are present in the Metatheria; and (3rd) the *dorsal commissure of the pallium*, which has been added in the Eutheria. The latter fibres insinuate themselves between the other two series of fibres, the morphologically caudal extremity of the dorsal commissure remaining hippocampal, the cephalic extremity containing the fibres from the precommissural area. The rapid increase of the pallial part of the commissure soon throws these two more ancient commissures into insignificance.

One is now prepared to briefly discuss what exactly is meant by the term 'corpus callosum.'

In the seventeenth century one finds writers, such as William Cowper (27), speaking of the 'corpus callosum' in the sense of the whole white matter of the cerebrum, because it is hard and firm compared with the grey matter. I am aware that other derivations in abundance have been advanced, as Cruveilhier has pointed out, but this appears to me a much more plausible explanation than any he adduces. Cowper speaks of the great *trabs cerebri* as the *pars transversalis corporis callosi*. But even fifty years before his time Continental anatomists were using the term in the same sense as Cowper's *pars transversalis*. Since the beginning of the eighteenth century it has retained this latter significance until quite recently.

The recognition of the hippocampal commissure as a distinct morphological division of the great commissure has impressed upon most observers the advisability of drawing some distinction between the two series of fibres. Hence the hippocampal commissure has been by the great majority of anatomists excluded from the corpus callosum. A number of writers, however (Ganser and Paul Martin among them), ignoring the great morphological and phylogenetic factors which distinguish these two series of fibres, and militate against their being bunched into one incongruous group, persist in still applying the term 'corpus callosum' to the whole dorsal commissure.

The morphological and phylogenetic features which distin-

guish the commissure of the precommissural area from the *dorsal commissure of the pallium* are even greater than those which separate the latter from the hippocampal commissure, since the precommissural area and its commissure are phylogenetically more ancient. Hence there is even less reason for grouping this commissure with the pallial commissure than there is in the case of the hippocampal. Yet His, while distinguishing hippocampal from pallial commissure, includes the commissure of the precommissural area with the latter. It is the signal merit of Reichert of recognising the latter, which he called *commissura pedunculorum septi* (27), although he did not appreciate its deep morphological significance. Henle called it '*Commissura baseos alba*.' Concerning this, His (28) says, "Das was mit diesen Namen beschrieben worden ist, ist die Endplatte des Balkenschnabels (die *Lamina rostralis* unserer Liste)."

It would appear, then, that the older anatomists have included under one category three heterogeneous series of fibres, to which collectively the name 'corpus callosum' has become attached, after being divorced from its original meaning. It is perhaps useless now to protest against the want of meaning in the term itself, seeing that Gerdy and Broca, among many others, have protested in vain. But surely it is not too much to expect, now that a definite knowledge of its evolution and morphology is dawning, that some uniformity in the application of the term will be adopted. The literature relating to the cerebral commissures within recent years affords but too clear an indication of the utter chaos which such a confused and uncertain nomenclature can produce. To be consistent, the term 'corpus callosum' must either be restricted to the *dorsal commissure of the pallium*, which forms the great bulk—practically the whole—of the commissure in man, and which is found only in Eutheria; or, on the other hand, it must include both the hippocampal commissure and the commissure of the precommissural area, *i.e.*, the whole of the dorsal commissure in all animals.

The confusing element is at once apparent if the latter definition be adopted, for then one must admit that a corpus callosum is present in all vertebrates—a statement which can only be a never-ending source of confusion to the morphologist, and help to maintain the discussion of the commissures at the same stage

that it has occupied for the past fifteen years, *i.e.*, little else than a verbal quibble.

For if this definition be adopted, one could then say that the dorsal commissures of the frog, snake, and man were all corpus callosum, and an unwary student might—and pardonably—conclude that the three commissures were homologous. Whereas the dorsal commissure of the frog is mainly derived from the precommissural area, that of the snake is mainly hippocampal, and that of man is almost wholly pallial. To apply the name to the whole dorsal commissure is only likely to perpetuate the confusion which has been such a stumbling-block to the comparative neurologist within recent years.

The confusion in nomenclature is surely disconcerting enough ; but when writers, taking advantage of a meaningless term, set up criteria, as false as they are illogical, of a corpus callosum, such criteria as suits each individual's purpose or preconceived ideas, it is not surprising for a new investigator to find his path strewn with appalling obstacles in the shape of a chaotic literature, in which extensive and valuable contributions to our knowledge have been sacrificed to these vicious influences.

For instance, when one recollects that the vast bulk of the hemisphere of higher mammals is pallium, and that in reptiles the pallium is so insignificant and ill-defined as to be with difficulty recognised, the absurdity of comparing the commissures of two such brains upon a topographical basis, and homologising two commissures simply because they connect the parts that happen to be dorsal in the two hemispheres, as Osborn does (29) (quite regardless of the fact that the dorsal part of one hemisphere is hippocampus, and of the other pallium), is apparent, and needs no further comment.

This is but a sample of the transparently false criteria which have been set up in great profusion in recent years.

The moral of all this is, that if the science of anatomy is to free itself from the retarding influence of such illogical and paralysing factors, it must either be altogether rid of the absurd and worse than useless term 'corpus callosum,' or restrict it to the *dorsal commissure of the pallium*, which is present only in Eutheria.

(23) "Ueber d. Riechbündel des Cornu Ammonis," *Anat. Anz.* iii., 1888.

(24) "The connection between Olfactory Bulb and Hippocampus," *Anat. Anz.*, Bd. x. Nr. 15.

(25) *Loc. cit.*

(26) In reviewing the paper which I contributed to the Linnean Society on the cerebral commissures (*loc. cit.*), Herrick, in the *Journal of Comparative Neurology* of July 1895, ridicules as an extravagant idea this statement that the homologues of the fibres of the dorsal commissure of Eutheria are found in the ventral commissure of Metatheria. This statement, however, is no mere idea, or even opinion, but a matter of direct observation, which any one who is not too deeply biassed by preconceived ideas must admit. If Herrick (who has devoted a considerable amount of attention to the brain of *Didelphys*) is so wilfully blind to the fact that certain pallial areas are in the Metatheria connected by fibres passing in the *ventral* commissure, and in the Eutheria by fibres passing in the *dorsal* commissure, no amount of argument is likely to show him the utter groundlessness of his own hypotheses, and the weakness of the position he so complacently assumes.

It is surely illogical enough to call the cephalic extremity of the hippocampal commissure and the commissure of the precommissural area (in reptiles and *Didelphys*) by the name 'corpus callosum'; but when, in figures of transverse sections of the *Didelphys* brain (*Journal of Comparative Neurology*), he labels the uncrossed precommissural fibres of the fornix system as 'corpus callosum' also, one is seriously inclined to question what the writer considers as a commissure.

In the same critique he accuses me of confusing 'gyres' and 'tracts.' This from a writer who calls the 'fascia dentata' the gyrus fornicatus is perhaps fair comment.

(27) "The Anatomy of the Human Body."

(27) "Bau des menschlichen Gehirn." Berlin, 1861, ii. s. 70-76.

(28) "Die Anatomische Nomenclatur," *Arch. f. Anat. u. Phys.*, 1895, Suppl. Band, p. 171.

(29) "The Origin of the Corpus Callosum, etc.," *Morph. Jahrb.*, Bd. xii.

EXPLANATION OF REFERENCES TO FIGURES IN TEXT.

alv.—alveus.

a.f.—columna fornicis.

c.d.—*commissura dorsalis* (hippocampi).

c.v.—*commissura ventralis* (seu anterior).

cer.—cerebellum.

c.m.—corpora mammillaria.

c.st.—corpus striatum.

e.o.r.—'external olfactory radiation' lying upon the pyriform lobe.

f.d.—fascia dentata.

FIG. 12.—Base of Brain of Ornithorhynchus.

- fl.*—fimbria.
- fl.*—flocculus.
- f.r.*—fissura rhinalis (ecto-rhinalis).
- f.e.*—fissura endorhinalis.
- h.f.*—hippocampal fissure.
- hip.*—hippocampus.
- l.v.*—lateral ventricle.
- med.*—medullary matter of hemisphere.
- n.c.*—nucleus caudatus.
- n.l.*—nucleus lenticularis.
- n.a.*—nucleus amygdalæ.
- o.b.*—olfactory bulb.
- olf. inv.*—olfactory invagination.
- olf. n.*—olfactory nerves.
- op.*—optic tract.
- ped.*—olfactory peduncle.
- pl.*—pallium.
- p.a.*—'precommissural area.'
- pons*—pons Varolii.
- pyr.*—pyriform lobe.
- p.d.*—'area depressa.'
- s.*—'commissure-bed' or septum.
- s.g.*—stratum granulosum of *f.d.*
- s. med.*—stria medullaris.
- st.t.*—stria terminalis.
- t.o.*—tuberculum olfactorium.
- t.V.*—*tuberculum quinti.*
- thal.*—optic thalamus.
- vall. syl.*—vallecule Sylvii.
- IV n.—Fourth nerve.

SYDNEY, N.S.W., March 13, 1896.

HALICHÆRUS GRYPUS: THE GREY SEAL. OBSERVATIONS ON ITS EXTERNAL APPEARANCES AND VISCERAL ANATOMY. By DAVID HEPBURN, M.D., MC., F.R.S. Ed., Lecturer on Regional Anatomy, University of Edinburgh.

(Continued from page 419.)

IV. EXAMINATION OF THE VISCERA.

(a.) Alimentary System.—

The œsophagus was a powerful muscular tube, lined by a mucous membrane thrown into longitudinal rugæ. When stretched, the mucous membrane presented a uniform surface, studded with numerous fine granular points, as if dusted with sand. Close to its junction with the stomach it measured $2\frac{1}{2}$ inches in diameter, and very readily admitted my hand and forearm.

The stomach, emptied of its contents, and lying flaccid on a table, presented a lesser and a greater curvature, to each of which there was attached a corresponding omentum. Close to the pyloric end of the lesser curvature there was a slight diverticulum or sacculation projecting in the direction of the liver.

The œsophageal end of the stomach presented a cardiac enlargement on its greater curvature, but it did not rise above the level of the cardiac orifice. The most pronounced bulging on the greater curvature was seen in its pyloric half. The external diameter at the cardiac orifice was similar to the width of the œsophagus, viz., $2\frac{1}{2}$ inches; externally the pylorus measured 1 inch in diameter. The position of the pylorus was indicated by a strong resistant ring, almost cartilaginous in its consistence. The greatest transverse diameter of the stomach in its empty state, from the pyloric orifice to the great curvature, was 12 inches; the greatest length from the œsophageal orifice to the greater curvature at a point in the pyloric half of the great curve was 14 inches.

There was an abrupt, distinct, but not absolutely straight line

of demarcation between the gastric and œsophageal mucous membranes. In the stomach, the mucous membrane was darker, thicker, and more spongy than in the œsophagus; and when slightly stretched, numerous pit-like openings became visible.

I passed my hand and forearm through the œsophagus into the interior of the stomach, and onwards towards the pylorus. At a point on the lesser curvature, 4 inches from the pylorus, something of the nature of a curtain or partition projected towards the interior of the stomach from the lesser curve. As a consequence of this arrangement, the cavity of the stomach formed a recess on the pyloric aspect of this curtain. By changing the position of my hand and passing it along the great curvature, I found no obstacle to its progress as far as the pylorus, through which it was impossible to force my finger into the duodenum, because the passage was blocked by a rounded, valve-like, and fairly rigid pad, projecting from the inferior or hinder aspect of the pylorus. However, by reversing the position of my hand and applying it to the lesser curvature, a passage into the duodenum was easily effected, although in this position there was also a smaller projecting valve-like pad. The pyloric orifice would only transmit my middle finger, which implies a diameter of slightly more than half an inch.

When the stomach was inflated to a moderate size, a very acute flexure was seen in the region of the lesser curve, nearer to the pylorus than to the œsophagus. The sides of this flexure were maintained in close apposition by the gastro-hepatic omentum, and it was at once evident that this feature of the stomach wall accounted for the projecting curtain found on the internal aspect.

In its partially distended condition the stomach somewhat resembled an inverted egg-shaped retort,—the œsophagus being attached to the larger end, the abrupt flexure representing the neck, and the pyloric dilatation the wide outlet, from which the duodenum was continued. No doubt the acute flexure in the stomach wall is a mechanical arrangement for securing an effective circulation of its contents, whereby undigested masses would be directed against the greater curvature, while their escape through the pylorus would be easily prevented by its strong valvular pads. Certainly, although large masses of

partially digested material were found in the interior of the stomach, only the finest pulp, pinkish and pasty, was seen throughout the intestine.

The contents of the stomach consisted entirely of the remains of fishes, in various stages of digestion. Numerous vertebræ, representing fish of various sizes, skull-bones, jaw-bones, spines, ribs, and fin-rays, besides quantities of ova, were found. The largest vertebræ were identified¹ as belonging to a specimen of *Lophius piscatorius*, of at least 2 feet in length; and, from the absence of the large skull-bones of this animal, probably the seal bit off and rejected the bulky head of this fish. The majority of the other bones represented *Gadidæ* of different sizes; and, judging from the state of their vertebral columns, probably these were swallowed entire.

Small Intestine.—For about a foot, the small intestine was disposed in relation to the head of the pancreas, and this portion may be regarded as the duodenum. Three inches from the pylorus it received the common bile-duct and the pancreatic duct on its dorsal aspect. These ducts entered the intestinal wall in close proximity to, but distinct from, each other. They perforated the wall very obliquely, and without communicating with each other. Their orifices were sufficiently oblique to enable the duodenum to retain air forced into it from the stomach, but air pumped into the duodenum from its distal end readily escaped by the ducts in question.

The coils of the small intestines (jejunum and ileum) were very elaborate, and were retained in position by a mesentery attached to the dorsal aspect of the abdominal wall in a transverse direction. Between the peritoneal layers of the mesentery, and close to its base, there was one large gland measuring 9 inches in length. The average depth of the mesentery was 8 inches.

Large Intestine.—The longitudinal muscular fibres of the large intestine were disposed in a continuous stratum, and therefore its wall was non-sacculated. In length it measured 2 feet, exclusive of the rectum, which was rather more than 1 foot.

¹ I have pleasure in acknowledging the ready assistance of Mr James Simpson, of the University Anatomical Museum, and of Mr Eagle Clarke, of the Museum of Science and Art, Edinburgh, in identifying these specimens.

The *Cæcum* was situated close to the duodenum, and was devoid of a vermiform appendix. Measured from the lower margin of the ileum, at its line of junction with the colon to its free end, the cæcum extended 2 inches. A peritoneal fold—ileo-cæcal ligament—attached the ileum and cæcum to each other. The cæcum was distinctly narrower throughout its entire length than the colon, but the narrowest part was a distinct constriction half an inch from the nearest point of the ileo-cæcal line of junction. This constriction might be regarded as indicating a rudimentary stage in the separation of cæcum into cæcum proper and vermiform appendix.

Ileo-cæcal Valve.—Having made an aperture in the colon opposite its junction with the ileum, it was possible to examine the valvular arrangements of the ileo-cæcal orifice. These were very imperfect, and were disposed in relation to a circular opening not quite so large as the lumen of the small intestine. The folds of lining membrane, which played the part of valves, were not of sufficient size to occlude the orifice. They were arranged more especially in relation to the dorsal, ventral, and hinder aspect of the orifice. On the *hinder* or *cæcal aspect* of the orifice a dorso-ventral fold of a somewhat triangular appearance was situated. Its apex and sides were fused with the wall of the cæcum, but its base was crescentic and free, and directed forwards. From the dorsal extremity of this crescentic border the valvular fold was continued into a small *dorsal* valve, having a semilunar outline. A third and more extensive semilunar fold was situated on the *ventral* aspect of the orifice. Both horns of the semilune were visible from the interior of the colon. The hinder horn faded on the surface of the hinder or cæcal flap, the anterior horn fused with the wall of the colon in front of the crescentic dorsal flap, and thus both extremities of the dorsal valve were embraced by the ends of the ventral one. From the angle at which the ileum joins the colon, it is quite clear that the fusion of their contiguous walls is sufficient to account for the triangular flap or valve on the hinder or cæcal aspect of the ileo-cæcal orifice. Further, it is interesting to note that this triangular hinder valve corresponds in position to the inferior or perpendicular flap of the corresponding valvular apparatus in man; and that, by a fusion of the contiguous horns

of the dorsal and ventral semilunar folds, accompanied by such an increase of their size as would reduce the antero-posterior diameter of the orifice, we should practically reproduce the valvular arrangements familiar in man.

The *colon* was not differentiated as in man.

The *rectum* possessed a well-defined mesentery in its anterior half.

The *liver* was a bulky multi-lobulated organ, and when removed from the body it no doubt underwent considerable flattening.

Its *diaphragmatic surface* measured 23 inches laterally, and from 10 to 18 inches in the dorso-ventral direction. The falciform ligament and ligamentum teres were well marked, and the general surface of the organ was cleft to varying depths by a number of fissures. To the left side of the falciform lig. there were *two* lobes, the smaller one being nearest to the left border. To the right side of the falciform lig. there were *three* lobes, the smallest being situated between the lig. teres and the deep fissure in which the fundus of the gall-bladder appeared.

The *abdominal surface* of the liver was also much lobulated. In addition to those lobes already described on the diaphragmatic surface, there was another which was continuous with the Spigelian lobe, and which hung *pendulous* from the right end of the hilum. The *hilum* measured 5 inches in the transverse direction. In its general plan, this surface conformed to what is found in man. Thus, the *lob. quadratus* was situated between the hilum and the deep fissures which were occupied by the lig. teres and the gall-bladder respectively. The *Spigelian lobe* was placed between the hilum and the grooves occupied by the inferior vena cava and the ductus venosus respectively. In this way three lobes—including the pendulous one, which was in reality a *lob. caudatus*—were left to represent the remainder of the right lobe of human anatomy, while the left lobe of the human liver was represented by the two lobes already referred to as lying to the left side of the falciform ligament. The *lig. teres* (obliterated umbilical vein) was crossed by a *pons hepatis*. This ligament was patent to a distance of 4 inches from the liver. Further, the unobliterated lumen communicated with the portal vein at the left end of the hilum, while the *ductus venosus*, which was continued to join vena cava inferior, was patent throughout

its entire length, and quite readily admitted a dissecting-room blow-pipe.

The *gall-bladder* was empty, and, as already mentioned, it occupied a deep fissure on the abdominal aspect of the liver, while its fundus projected towards the diaphragmatic surface, and extended some distance beyond the ventral border of the liver. The termination of the bile-duct has already been referred to.

The *spleen* was a flattened organ, attached to the left aspect of the greater curve of the stomach by the gastro-splenic omentum. It was also suspended to the lumbar region by the phrenico-splenic ligament. Its maximum length was 14 inches and its maximum breadth 5 inches. The anterior or ventral border presented numerous notches, and on its outer surface there were half a dozen slit-like depressions, none of which were more than an inch and a half in length. On its gastric surface there were two longitudinal and parallel lines of entrance for blood-vessels. The interval between these lines was covered by peritoneum belonging to the lesser peritoneal sac. This area was slightly lobulated, and presented two or three projecting portions of spleen substance.

The *pancreas* was not at any point in contact with the spleen. The association of small intestine with the head of the pancreas and the termination of the pancreatic duct have already been mentioned.

(b) *Genito-urinary System*.—

The *kidneys* showed elaborate venous networks upon their surfaces. Each kidney measured 8 inches in length by 4 inches in width.

A *supra-renal* body, flattened and ovoid, measuring 2 inches long and 1 inch wide, lay anterior to each kidney, but quite separate therefrom. The veins from the supra-renal body joined the renal venous plexus.

The *urinary bladder* was an elongated fusiform organ reaching well forwards towards the umbilicus, and continued thereto by a distinct *urachus*. On the lateral aspects of the urinary bladder, the obliterated hypogastric arteries were readily visible.

There was no scrotum. Each *testis* occupied a recess in the abdominal wall, and separated from its fellow by the sheath

containing the penis. Each testis measured $3\frac{1}{2}$ inches in length and 2 inches in width. The *epididymis* formed a globus major and globus minor. No hydatids of Morgagni were seen.

The cavity of the *tunica vaginalis testis* was directly continuous with the abdominal cavity through the inguinal canal, which was quite open. The inguinal canal measured a little more than 2 inches in length, and its diameter was about half an inch.

The *corpora cavernosa penis* contained a bony growth situated in the anterior half of the free portion of the penis. The *urethra* separated very readily from the *corpus spongiosum penis*, within which it lay.

The *dorsal vein* of the penis was provided with many paired valves.

(c) *Respiratory System*.—

The *epiglottis* was a soft, easily flexible organ, possessing a broad base and a pointed glossal extremity, which was only free to a very slight extent.

The *larynx*.—Examined with the mucous membrane in position, the superior opening of the larynx presented prominent aryteno-epiglottidean folds. The rima glottidis measured $1\frac{1}{2}$ in. in length. The dorsal half of this interval was bounded by the contiguous surfaces of the arytenoid cartilages, the ventral half by the true vocal cords. There were no false vocal cords, nor ventricles to the larynx. When the epiglottis sank downwards and backwards, it formed a cushion immediately above the true vocal cords, and completely obscured them, but did not overlap that section of the rima situated between the arytenoid cartilages. The absence of false vocal cords renders it highly probable that the seal does not use its fore limbs for purposes of defence, as they are usually seen only in those animals which can strike a blow with the manus.

Some points of interest in connection with the intrinsic muscles of the larynx were noted as the result of modification in the shape of the cartilages. The *pomum adami* was very short in relation to the size of the thyroid cartilage, and, in consequence, there was a large interval between the cricoid and thyroid cartilages. This interval was somewhat reduced by the position of the crico-thyroid muscles, whose contiguous borders

with the lower margin of the thyroid cartilage formed the sides of a lozenge.

The *posterior crico-arytenoid* muscle arose from the posterior surface of the cricoid cartilage, and from a mesial fibrous septum attached to a ridge which separated it from its fellow. The fibres converged to be inserted into the outer angle at the base of the arytenoid cartilage. A small slip, composed of its most external fibres, became continuous with the external portion of the thyro-arytenoid muscle.

The *lateral crico-arytenoid* muscle was much smaller than the posterior. Its fibres arose from the sloping upper margin of the cricoid cartilage, and were inserted into the muscular process of the arytenoid cartilage in front of the posterior crico-arytenoid muscle.

The *thyro-arytenoid* muscle differed essentially from the corresponding muscle in man. It arose in one slip from the inner aspect of the ala of the thyroid cartilage close to the pomum adami. The fibres passed backwards to be inserted into the muscular process of the arytenoid cartilage, and some of them were continuous with the outer fibres of the *posterior crico-arytenoid* muscle, thereby lying external to the insertion of the *lateral crico-arytenoid* muscle. The muscle under consideration corresponded very closely to that section of the human thyro-arytenoid figured in Quain's *Anatomy*,¹ and named the *small thyro-arytenoid* muscle of Sæmmerring.

The thyro-arytenoid of human anatomy was also represented in this seal, but it had no attachment to the thyroid cartilage. In the seal, this muscle arose from a mesial raphé on the anterior or ventral aspect of the crico-thyroid membrane, and also from the outer surface of this membrane. The fibres were partly horizontal and partly oblique, the former being external to the latter. The muscle was inserted into the anterior border and muscular process of the arytenoid cartilage, subjacent to all the muscles already described. This is quite clearly the *great thyro-arytenoid* muscle of Sæmmerring, although the absence of attachment to the thyroid cartilage does not justify the use of the term 'thyro' in its description.

¹ Quain's *Anat.*, 9th ed., vol. ii. p. 534.

When the mucous membrane was removed from the posterior or dorsal aspect of the arytenoid cartilages, two strong muscles were exposed.

Each arose from the hinder and outer aspect of an arytenoid cartilage, extending as far outwards as the muscular process of the cartilage, and receiving an augmentation of fibres from the upper border of the great thyro-arytenoid muscle. The muscular mass thus constituted was inserted into a mesial dorsal cartilaginous nodule, perfectly distinct from both arytenoid cartilages, upon which it was superimposed, and on which it was freely movable. These muscles, therefore, had a disposition quite distinct from that of the arytenoid and aryteno-epiglottidean muscles of man, with which nevertheless their position to some extent corresponded.

Taking into consideration the mesial origin of the great thyro-arytenoid muscle, its partial continuity with the muscles just described, and their mesial and movable insertion, it is evident that between them they may exercise a certain sphincter action on the superior aperture of the larynx.

In the seal, the *aryteno-epiglottidean* muscle consisted of a few straggling fibres arising from the anterior border of the arytenoid cartilage, and extending towards the epiglottis in the soft tissues of the aryteno-epiglottidean fold of mucous membrane.

The *trachea* was remarkably strongly protected on all aspects by cartilaginous rings. Each *bronchus* entered the root of its own lung on the dorsal aspect of the great pulmonary artery and vein for the lung. In the dorsal-ventral direction these structures occupied the same relative positions as in man. In the left lung there was no eparterial bronchus, because, in the root of this lung, the pulmonary artery lay anterior to the first branch of the bronchus. In the case of the right lung, a large branch of its bronchus arose anterior to the *main stem* of the right pulmonary artery, but this artery gave an offshoot of some size to the apical lobe of the lung, in such a way as to obscure the origin of the first branch of the bronchus. Thus there was an eparterial bronchus, in the sense of its being anterior to the trunk of the artery, but it was not eparterial with reference to its position in contrast with the first branch of the pulmonary artery.

Lungs.—Each lung presented a thin ventral or sternal border and a thick dorsal one, while in the case of the left lung the external border showed a deep notch corresponding to the apex of the heart. Each lung presented one fissure, running in an almost transverse direction, but the fissure was imperfect, being for the most part shallow, and in some places obliterated. On the pericardial aspect of the right lung, a third lobe projected like an outgrowth close to the lower border of the root. Between the base of the right lung and the diaphragm there was a well-marked band, consisting apparently of pleural membrane. It presented two free surfaces and two free borders, and the presence of distinct blood-vessels within it seemed to indicate that it was a double layer of membrane. The entire absence of pleuritic adhesions elsewhere tended to show that this was a pleural ligament. At the same time there was no trace of a similar structure in connection with the left lung.

(d) *Circulatory System*.—

The fibrous *pericardium* was firmly attached to the diaphragm, and was continued on the trunks of the aorta and pulmonary artery. The anterior and posterior venæ cavæ pierced the pericardium as in man, and there was no left anterior vena cava.

The *serous pericardium* was disposed as in man, except that the aorta and pulmonary artery, although invested by a common serous envelope, were not nearly so closely in apposition as in the human subject. The vestigial fold of Marshall was indistinct.

The apex of the *heart* presented a shallow interventricular groove, situated to the right side of the true apex, but scarcely deep enough to call a notch.

The *coronary sinus* was very large, and the orifices of its tributaries were guarded by two semilunar folds of the lining membrane.

The interior of the *right auricle* presented characteristic appearances as regarded its walls. There was no Eustachian valve to the posterior vena cava, but the fossa ovalis was nearer to the mouth of the post vena cava than in man. The annulus ovalis formed a very distinct projecting ridge on the side of the fossa next the anterior vena cana. Only fenestrated remnants remained to represent the valve of Thebesius. In the right

ventricle there was nothing exceptional, and a well-marked moderator band was present. In the left auricle and ventricle the various appearances and structures were typical. Special care was observed in opening the left ventricle, but no moderator band was visible.

The position of the *abdominal aorta* attracted attention. By reason of the enormous size of the psoas muscles, the lumbar vertebræ were entirely hidden, and the aorta, instead of being in contact with the vertebræ, occupied the narrow groove between the adjacent margins of these two muscles. It bifurcated into two common iliac arteries in the usual way. From its *dorsal* aspect a series of *unpaired* branches took origin. The last of this series was the *arteria sacra media*, while those in front were lumbar arteries. Each *lumbar* artery proceeded dorsally between the two psoas muscles until it came close to the body of a lumbar vertebra, when it bifurcated and sent a branch past each side of the vertebral body.

The *middle sacral artery* arose from the dorsal aspect of the abdominal aorta, two inches in front of its point of bifurcation, a quarter of an inch behind the level of origin of the inferior mesenteric artery, and in line with the series of unpaired lumbar arteries. It coursed backwards along the pelvic surface of the sacrum situated in the middle line, and supplying a series of paired branches directed laterally towards the anterior sacral foramina.

The aorta terminated by dividing into common iliac arteries, each of which was one inch in length, and again each common iliac artery bifurcated into external and internal iliac branches. The former gave off a large deep epigastric branch, and the latter was continuous with the obliterated hypogastric vessel. A comparison of this mode of termination of the aorta with that which prevails among the carnivora generally, reveals several pronounced differences. Thus, among carnivora generally, there are no common iliac arteries, but the external iliac arteries arise independently from the aortic trunk, while the internal iliac arteries spring from the bifurcation of the diminished aorta, and the middle sacral artery arises from the dorsal surface of the aorta immediately in front of its point of bifurcation. These conditions differ very markedly from what has just been described

in the grey seal, in which the presence of common iliac arteries and the point of origin of the middle sacral artery suggest several interesting questions in connection with their morphology. As is well known, the permanent aorta is formed by the more or less extensive fusion of the *primitive dorsal aortæ*. Anatomists differ, however, regarding the vessels which arise from the unfused hinder ends of the primitive aorta and the mode of origin of the middle sacral artery. The generally accepted view is, that the middle sacral artery represents the direct continuation of the aortic trunk, and that it results from the fusion of the primitive aortæ.¹ Furthermore, in Quain's *Anatomy* it is stated that "the common iliac arteries are formed by the persistence of the roots of the allantoic arteries," which are in the first instance "a direct continuation of the primitive aortæ."² There is without doubt a difficulty in reconciling these two statements.

Professor Young of Manchester has written an elaborate and instructive memoir dealing with this subject,³ and one or two extracts from his conclusions may be of interest here, before applying them to the elucidation of the appearances presented in the seal. He says, in the embryo "there is not a vestige of a caudal continuation of the aorta" (p. 219). "Before the tail is formed the allantoic circulation is established, and the primitive aortæ end posteriorly as the common stems of vitelline and allantoic arteries, and persist as the hypogastric arteries the presence or absence of common iliac vessels is determined by the extent to which fusion of the primitive dorsal aortæ extends backwards" (p. 220).

"If the middle sacral artery is to be regarded as the true backward continuation of the primitive dorsal aortæ, then the vessel which intervenes between the origin of the middle sacral and the terminal bifurcation can hardly be regarded as aorta at all. It is rather a common allantoic stem" (p. 223).

Returning now to the termination of the aorta in the seal and

¹ Quain's *Anat.*, 10th ed., vol. i. pt. i. pp. 44 and 147.

² Quain, *loc. cit.*

³ Young, "On the Termination of the Mammalian Aorta, with Observations on the Homologies of the Pelvic Arteries" (Studies in Anatomy from the Anat. Dept. of Owens Coll.), vol. i., 1891.

the origin of its middle sacral artery, we observe that this vessel arises much farther in front of the aortic bifurcation than is usually seen in other mammals, and therefore in quite a different relationship from that prevailing among other carnivora, in whom it arises between the origins of the external and internal iliac arteries.

To my mind this mobility of the point of origin of the middle sacral artery of the seal, as compared with other carnivora, suggests the priority of the aortic trunk, and the formation of the middle sacral as a collateral branch rather than the formation of the smaller vessel by fusion of two primitive aortæ. Moreover, I think that this view receives support from the presence of a whole series of unpaired lumbar arteries arising from the dorsum of the seal's aorta, for whose origin we could scarcely claim the fusion of paired vessels, any more than we can advance such an argument to account for the unpaired vessels arising from the ventral aspect of the aorta.

Further, if the middle sacral artery of the seal be held to represent the fusion of the primitive aortæ, it is quite clear, as Professor Young suggests, that the last two inches of its permanent aorta are in reality not aorta, but a "common allantoic stem," resulting from the fusion of another pair of vessels. While fully recognising the fact that paired arteries fuse, and so form single trunks, it does not seem necessary to resort to this explanation of the origin of every mesial arterial trunk. At the same time, even although the middle sacral artery should develop from the fusion of a pair of longitudinal vessels, and although its mesial position and the manner in which it supplies paired collateral branches render it peculiar among aortic branches, yet the comparatively late period at which the tail grows backwards, to a large extent excludes this vessel from being regarded as the direct aortic continuation.

In Young's memoir, already referred to, there are only two instances in which the middle sacral artery is undoubtedly a continuation of the aorta, viz., the opossum (*Didelphys Virginiana*) and the porpoise (*Phocaena communis*); but, on the other hand, the vessel is entirely wanting in the zebra (*Equus burchelli*), hyrax, hedgehog (*Erinaceus Europæus*), and fruit bat (*Pteropus*), while in the armadillo (*Dasypus sexcinctus*) it is double.

According to Owen,¹ in the Unau (*Cholæpus Hoffmanni*) the aorta gives off common iliac arteries. I have verified this statement by the dissection of a specimen. In addition, the middle sacral artery arose from the dorsum of the aorta, immediately in front of its bifurcation.

Moreover, the common iliac arteries gave off two small branches to the interior of the pelvis before they bifurcated into external and internal iliac branches,—the latter being directly continuous with the obliterated hypogastric trunks.

In the Grey Seal, the *inferior mesenteric artery*, already referred to, arose from the ventral surface of the aorta, two and a quarter inches in front of the bifurcation. Its terminal branch entered the meso-rectum in the usual way.

¹ Owen, *Anat. of Verts.*, iii. p. 544.

OSSIFICATION OF THE THIRD TROCHANTER IN MAN.

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SOME time ago I noticed that the femur of a young subject dissected in the School of Anatomy, Trinity College, Dublin, possessed, in addition to the usually described epiphyses, a small epiphysis for the gluteal ridge or third trochanter. The subject was a male of about seventeen years of age, and unfortunately the left femur only was preserved. The epiphysis for the third trochanter is a flat narrow scale of bone placed with its long axis corresponding with that of the shaft of the femur. Its upper end corresponds to the level of the lowest part of the small trochanter, while its lower end lies just above the groove so often present in the region of insertion of the gluteus maximus muscle (see 2 of figure). The epiphysis measures 25 mm. in length, and is 12 mm. across in its widest part. I have made an examination of a large number of femora in the Anatomical Department of Trinity College, and also of a number of young and adult bones kindly lent for the purpose by Prof. Cunningham from his private collection, and have found similar epiphyses in two other young bones. One of these (3 of figure) is the left femur of a boy of fifteen years; the other (1 of figure) is the right femur of an older individual, but the sex is not noted. In neither of these latter specimens is the epiphysis of the third trochanter as extensive as in the femur first described. In one, indeed, it is not more than 5 mm. in its longest diameter, while in the other it measures about 10 mm. In both cases its position corresponds with that described in the first case, its upper end being placed on a level with the lower part of the small trochanter. Although I have only been able to prove the presence of this epiphysis in the three femora figured, yet the appearance of the upper part of the gluteal ridge in a number of other bones leads me to believe that, in many cases at all events, this part of the bone is added to the femur as a special epiphysis.

With regard to the ossification of the third trochanter in those lower animals which possess one, I have been unable in the literature at my disposal to find definite information. An examination of a number of skeletons, however, shows that a special centre may be present for it. This is easily demonstrated in the rabbit, and another rodent—*Coelogenys paca*—preserved in the Natural History Museum, Trinity College, affords a beautiful example of the same fact. In the rabbit, the special centre simply forms a thin scale over the strongly marked third trochanter, while in *Coelogenys* it appears to form the whole third trochanter, which is here not so strongly

(1)

(2)

(3)

The upper parts of three young femora, to show the epiphysis for the
3rd trochanter (3rd T.).

developed. Among Perissodactyla, the tapir possesses such a centre,¹ and in the horse, although the usual descriptions do not take note of it, still Franck, in his *Anatomie der Haussäugethiere*, describes a centre for the third trochanter of the horse. It is,

¹ Specimens showing this are preserved in the Natural History Museum, Trinity College, Dublin, and also in the Museum of the Royal College of Science, Dublin.

however, he says, sometimes absent. I am indebted to Prof. J. M'Fadgean for this information regarding the femur of the horse. On the other hand, Owen, speaking of the third trochanter of the rhinoceros, says "ossification sometimes extends from the great trochanter to the third trochanter." I have had no opportunity of examining a young specimen of this animal, yet I would venture to suggest that in the rhinoceros also a special centre may be present both for the third and the great trochanter, and that they unite in some cases to form a single epiphysis. This might give rise to the appearance of an extension of ossification from the great to the third trochanter. In one specimen of *Cœlogenys paca* that I have had an opportunity of examining, the epiphyses of the great and third trochanters are in actual contact, although distinct. The fact that the third trochanter of man thus closely resembles in its mode of development that of lower mammals adds to it an interest, especially as the presence of this trochanter is stated to be a characteristic of the femora of higher rather than of lower races, and of man rather than of apes.

**NOTE ON AN OBLIQUE INTEROSSEOUS RADIO-ULNAR
LIGAMENT FOUND IN THE PUNJABI.** By J. C.
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Two oblique interosseous radio-ulnar ligaments are commonly recognised, one a superior band known as the superior oblique ligament or oblique ligament proper, and the other an inferior band called by Morris the inferior oblique ligament.

In addition to these named ligaments, one usually finds on the posterior surface of the interosseous membrane other oblique bands of fibres running in the same direction as these ligaments, that is to say, from above downwards and outwards, and opposite to the course of the general mass of the fibres of the interosseous membrane.

In the European these unnamed bands appear to be more or less inconstant, and attain no great size. In the Punjabi, on the other hand, one of these bands is constantly present, and frequently attains a very considerable size. The band in question

Posterior view of the radius and ulna, displaying the ligament described.

underlies the extensor ossis metacarpi pollicis, and is easily exposed by cutting through its tendon, and throwing the belly of the muscle upwards and outwards from its origin. Some of the fibres of the muscle take origin from this band. These are easily detached, and after their removal the band presents a smooth glistening surface. The band is narrow in the centre, and spreads out at either extremity, above on the posterior surface of the ulna, and below on the posterior surface of the radius.

It is attached to the posterior surfaces of these bones at some little but appreciable distance from the interosseous border.

Two good specimens of this band which I have measured have the following dimensions:—

	Specimen (1).	Specimen (2).
Width at ulnar attachment,	22 mm.	15 mm.
Width in centre,	9 mm.	6 mm.
Width at radial attachment,	27 mm.	24 mm.

The precise meaning of this band is not easy to understand. It is not tense in pronation, or like the oblique ligament in supination, but it is able to resist any force tending “to pull the radius with the hand from the humerus.”

SOME POINTS IN THE ANATOMY OF A SIRENOMELIAN MONSTER. By T. MANNERS-SMITH, M.A. (Cantab.), M.R.C.S., *Chief Demonstrator in Anatomy, Mason College, Birmingham.*

THE following is a brief description of certain features of a Sirenomelian monster, which recently came into my possession through the kindness of Dr Windle.

In the January number of this *Journal* (2) I gave an account of two Symelian monsters, but no reference was there made by me to the abdominal viscera, for the reason that such viscera had been removed before the specimens came into my possession. In the specimen under present examination all the abdominal organs were intact. I have therefore thought it well to add this supplement to my account. The anatomy of this specimen differs in some important particulars from what is usual in the class Sirenomeles, to which it belongs. These particulars I have noticed. I have not, however, given a minute description of the specimen, but have emphasised the chief points in which the monster differs from that to which I refer in the January number as my *second* specimen. I have also briefly described the urinary and genital organs.

Osseous System.

Unlike my previous specimen of Sirenomeles, the ilia were not fused into an iliac shield, but were separate; the ischia were, however, fused.

The femora were fused throughout their entire extent. There was a single pointed bone, resulting from the fusion of the two tibiae. Fibulae were absent.

A point of interest was the presence of two patellae, although both femora and tibiae were completely fused. In most cases where the patellae are separate, the femora are also separate, at least at their lower extremities, and the rudiments of two tibiae are present.

The Muscular System.

Gluteus maximus.—The two muscles were well developed and had the usual origin from the ilium; the fibres pass downwards and inwards towards the middle line, where the muscles of opposite sides blend in a somewhat triangular tendon, which is inserted into the middle of the shaft of the united femora. In the Sirenomelian described in my former paper this muscle was absent; it was also absent in very similar specimens described by Vrolik (3), Calomiatti, and Gebhard (1). The complete development of this muscle is interesting, since in most of the specimens hitherto examined and belonging to the class Sirenomeles, the muscle has either been absent or represented only by a few scattered fibres.

Between the muscles of opposite sides the rectum passes out to terminate at the imperforate anus.

The gluteus medius was also a well-developed muscle, and had the usual origin and insertion, but had, in addition, a slight intra-pelvic attachment. In the Sireniform described in my former paper the muscle was absent, as it was also in the specimens of the class Sirenomeles examined by the other observers.

The gluteus minimus was present, and was normal in its origin and insertion, with the exception that it had a slight intra-pelvic origin in addition. The muscle was absent in the specimen described in my former paper, and also in those specimens belonging to the class Sirenomeles of the other observers.

The presence of the three glutei is interesting, since in the specimens belonging to the class Sirenomeles hitherto examined the muscles have in all cases either been absent or vestigial. In the specimen described in my former paper the situation of the gluteal muscles was occupied by a large mass of fat, containing scattered muscular fibres. In the same specimen the iliac bones, however, were fused into an iliac shield, without any inferior aperture of the pelvis existing; the sciatic nerves were converted into flattened fibrous bands, and were entirely intra-pelvic. In the specimen under present description the ilia were not fused into one piece, but there was a considerable pelvic outlet, through which the rectum and the sciatic nerve passed. Most probably the absence of the gluteal muscles is a

In.

R.

K.

In.

Vd.

Rec.

Bl.

secondary change due to the degeneration of their nerve supply, in consequence of the pressure to which the nerves are subjected by the innominate bones fusing to form an iliac shield.

The small external rotator muscles were absent, as in most other Sirenomelians. There was a total absence of the hamstring muscles, as in the cases of most of the specimens belonging to the other observers, whether Symeles, Uromeles, or Sirenomeles. The remaining muscles were present, and had very similar origins, insertions, and positions to those of my previous specimens, and to those of the specimens of other observers which belonged to the class Sirenomeles.

The external genitals were totally absent, as is the custom in these monsters.

The testes were present, were well developed, and were situated outside the abdomen, in the inguinal region. They rested on the external oblique muscle.

The vasa deferentia passed through the inguinal canals and entered the abdomen, but, instead of entering the bladder, they joined the rectum near its upper end and on its posterior surface. At their point of entry they were situated close together. They are seen in the diagram somewhat on the stretch, and entering the rectum on its posterior aspect.

The small intestine was normal, as also was the cæcum. The large intestine terminated, in the region of the sigmoid flexure, in a cone-shaped blind extremity. The rectum was about 2 inches in length; it was blind at its commencement, and again at its termination, since the anus was imperforate. The vasa deferentia entered it as already mentioned.

The chief interest of the specimen, however, resides in the urinary system. It has generally been stated that, whilst the kidneys, ureters, and bladder may or may not be present in the Symeles and Uromeles, in the Sirenomeles no trace of these organs can be discovered. The present specimen derives especial interest from the fact that, although belonging to the class Sirenomeles, both kidneys and bladder were present. The kidneys were large, and were situated in the region of the 1st, 2nd, and 3rd lumbar vertebræ. They had not, however, the usual kidney shape or structure, but were converted into large cysts, the cyst-wall being formed by the thinned-out portion of

the kidney substance. Each kidney possessed a small renal artery.

The bladder was well developed but small, having a length of about half an inch; it terminated below in a urethra, which had a length of about an inch.

The presence of urinary organs is interesting, since it has been generally held that these organs are absent in the class *Sirenomeles*, though they may be present in the other two classes. It has also been supposed by some that the absence or deficiency of the urinary organs in the three classes was an integral factor of the monstrosity, and had some relation to or connection with its causation. Thus, W. Vrolik (4), after condemning the idea that this monstrosity is due to absence of one of the umbilical arteries, holds that *Sympodia* is due to some original malformation of the pelvis and its viscera, of which the cause remains unknown.

He states that from simple coalescence of the lower extremities cannot be derived the imperfect state of the uropoietic viscera. I should regard the absence or deficiency of the urinary organs as due entirely to a secondary change, dependent upon the pressure to which the bladder and kidneys are subjected by the retained urinary secretion, in consequence of the blind condition of the urethra. The cystic condition of the kidneys in my specimen would strongly support such a view; for although in the present instance the walls of the kidneys, though thin, were recognisable as consisting of kidney substance, we can imagine such a condition of increased pressure that the thin wall might easily rupture, and the kidney, shrinking to a small mass, could easily be overlooked on superficial examination.

The bladder, too, after rupture, might shrink to a small structure, rendering its recognition difficult.

The absence, then, or incompleteness of the urinary organs must not be regarded as an integral part of the condition of this monstrosity, but must, like the absence of the gluteal muscles, be looked upon as a secondary change, due entirely to pressure.

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EXPLANATION OF FIGURE, p. 509.

Shows certain of the abdominal viscera. The large cyst-like kidney, *K.*, not possessing the normal shape, being more or less oval in outline; there is no trace of a hilum. The vasa deferentia, *Vd.*, terminate in the rectum, *Rec.*, which commences above in a blind extremity. The bladder, *Bl.* is shown, but no trace of a ureter could be discovered. The large intestine, *L.Int.*, is seen terminating in a blind extremity, *Sg.* *S.In.*, small intestine. *R.*, rib. *Te.*, testicle.

ON THE MAMMALIAN HYOID, WITH ESPECIAL
REFERENCE TO THAT OF *LEPUS*, *HYRAX*, AND
CHOLÆPUS. By G. B. HOWES, Sec. L.S., F.Z.S., *Professor*
of Zoology R. Coll. Sci. Lond. (PLATE VIII.)

IN the year 1879, while investigating the detailed anatomy of the head of the common rabbit, I was much exercised about the presence of a small bone (*h.s.*, fig. 1) in direct articulation upon the paroccipital process (*p.o.*). Eight years later, in reviewing the first edition of Marshall and Hurst's *Practical Zoology*, I directed attention to it in print¹; and it is a remarkable fact that neither in that book nor in any of the numerous laboratory treatises current in our own language which deal with our familiar rodent is the structure even mentioned. I was unaware in 1879 that Krause had already briefly described it in his *Anatomie des Kaninchens*.² In the second edition of that work a fuller account of it is given, and the author regards it, as I had done, as the styloid element of the hyoid arch. Concerning its detailed relationships, however, I am now able to supplement his account.

It will be evident that if the bone in question really represents the 'styloid process' of other mammals, in respect to its free state and articulation upon the paroccipital process it is exceptional. The only structure at all comparable to it is a more familiar one, also free and in articulation with the otoccipital region of the skull, described by Brandt³ in *Hyrax*, and regarded by him as the possible homologue of the upper element of the anterior cornu of the hyoid. Flower is diffident about this homology,⁴ while George has denied the existence in *Hyrax* of an 'apophyse styloide.'⁵ As this is so, and as, in respect to details of relationship of the supposed styloid to the

¹ *Nature*, vol. xxxv. p. 503.

² Edit. 1, p. 149, 1868.

³ Brandt, *Mem. Acad. St Petersburg*. (7), Bd. xiv. p. 68.

⁴ Flower, *Osteology of the Mammalia*, Edit. 1, p. 177.

⁵ George, *Ann. Sci. Nat. Zool.* (Ser. 6), Tm. i. Mem. ix. p. 67.

skull and adjacent muscles in both *Lepus* and *Hyrax*, my own observations do not strictly accord with those of Krause and Hilgendorf, Brandt, and others, which are in themselves contradictory, I pass, firstly, to the consideration of detail.

Lepus cuniculus.—In the current edition of his *Anatomie*, Krause, with Hilgendorf, describes¹ the stylo-glossus, stylo-hyoid, stylo-pharyngeus, and digastric muscles as arising from the paroccipital (paramastoid) process of the exoccipital² (*p.o.*, fig. 1), the supposed styloid being said³ to be embedded in the tendon of that first named. On careful examination the conjoint tendons are found to be also attached to the mastoid process (*p.m.*), which, like the paroccipital, is elongated and styliform. The stylo-glossus tendon, however, may be distinct from the others (as at *m.sg.*, fig. 1); and when this is the case, it arises wholly from the mastoid process and is in no way related to the styloid. Comparison of such a specimen with one in which (as described by Krause and Hilgendorf) the stylo-glossus and stylo-hyoideus major (*m.s'*, fig. 1) arise conjointly, leaves little room for doubt that the 'styloid' is related rather to the latter than the former.

Krause describes the stylo-glossus as a single muscle. I find it invariably subdivided throughout its fleshy area into two unequally developed portions, as delineated in fig. 1.

The digastric muscle (*m.d.*, fig. 1) will be found to arise from the anterior border of the paroccipital process caudad of the 'styloid,' the stylo-hyoideus minor (*m.s''*) arising from its inner border. The stylo-hyoideus major (*m.s'*), while enclosing within its head the 'styloid' bone, arises from the paroccipital process, and on raising it a delicate slip (*m.sp.*) is to be found passing obliquely downwards and inwards to the pharyngeal wall. This is unquestionably the stylo-pharyngeus muscle referred to,⁴ but not fully described, by Krause. In that it arises internally to the stylo-hyoideus major, its relationships to that and the mastoid process are somewhat repetitional of those of the stylo-hyoideus minor (*m.s''*) to the digastric (*m.d.*) and the paroccipital

¹ Krause, *Anat. d. Kaninchens*, Aufl. ii. p. 87.

² *Loc. cit.*, pp. 76 and 139, the process being regarded (p. 76) as the transverse process of the last skull vertebra !

³ *Loc. cit.*, pp. 87 and 201.

⁴ Krause, *loc. cit.*, Aufl. ii. p. 87.

process (*p.o.*). This stylo-pharyngeus muscle blends with the stylo-hyoideus major at the level of the 'styloid' (*h.s.*); consequently, to be accurate, Krause's tendon of the stylo-hyoideus major must be regarded as the conjoint tendon of this muscle and the stylo-pharyngeus, and the 'styloid' bone must be defined as lying rather within that than within the stylo-glossus.

As for the 'styloid' itself, I find that variable only in respect to its occasional co-ossification with the paroccipital process, as in fig. 8.

Hyrax capensis.—The element (*hy.*, fig. 2) which in this animal would appear to represent the 'styloid' was described by Brandt¹ as a small pyramidal pointed ossicle, movably articulated by means of its broad base upon the anterior surface of the processus mastoideus. Flower, following Brandt, also speaks of this² as the 'mastoid process,' but M'Alister³ and George⁴ describe it as the paramastoid. Examined with care, the supposed 'styloid' (*hy.*, fig. 2) is found to be invested in a well-differentiated membrane continuous with the tendon of the stylo-glossus muscle (*m.sg.*), which is produced into a conspicuous fold along its anterior border. At its upper extremity the bone itself tapers away to a point, and is attached by fibrous tissue to the inner border of the stylo-mastoid foramen (*fo.*).⁵

Brandt's description insufficiently expresses its actual relationships to the adjacent bony structures. Mastoid process there is none, in the sense of a fully projecting 'processus muscularis.' If the supposed 'styloid' be removed (as in fig. 3), it will be seen that the mastoid bone and the paroccipital process both furnish the surface for its articulation, and that to effect the latter their anterior faces are produced into a keeled outgrowth (*ar.*) of a well-marked character. When the parts are in position the 'styloid' overlies this keeled surface, and it is so firmly held in place by the investing periosteum that play in an outwardly rotatory direction is alone possible.

This being so, the characters of the supposed upper end of the

¹ Brandt, *loc. cit.*, p. 68.

² Flower, *loc. cit.*, Edit. 1, p. 177.

³ M'Alister, *Morph. of Vertebrated Animals*, p. 282.

⁴ George, *loc. cit.*, p. 105.

⁵ Strictly, the stylo-mastoid and lacerum posterius conjoined under a remarkable modification of the peritympanic region of the skull.

hyoid arch of this animal are little less remarkable than those of its peripharyngeal portion, so well known.

Brandt, following Cuvier, speaks (*loc. cit.*) of a possible ligamentous connection between the 'apophyse styloïde' and the lower elements of the hyoid; and George (*loc. cit.*, p. 67) remarks, "l'apophyse styloïde n'existent pas; la pointe cartilagineuse qui représente la cornu antérieure est réunie par un ligament à l'apophyse paramastoïde." I can find no trace of any such ligament in the adult specimen which I have examined.

Concerning the lingual and pharyngeal muscles Brandt is very brief, but fuller descriptions are those of Murie and Mivart and of George.¹ The latter allocates to the stylo-glossus an origin from the paroccipital (paramastoid) process. In my specimen this is not the case, the muscle (*m.sg.*, fig. 2) arising from the supposed 'styloid.'

Murie and Mivart, following Meckel, have briefly described² a stylo-hyoideus muscle arising "from the paramastoid process behind the digastric, and inserted as usual (!) . . . strong and relatively thick." My own observations upon this (*m.s.*, fig. 2) are in harmony with those of George. I find it to be a delicate structure, arising conjointly with the digastric (*m.d.*), and inserted into the posterior border of the hyoid. In its detailed relationships it agrees with the stylo-hyoideus minor of the rabbit, and at first sight it would appear that the stylo-hyoideus major of that animal is in *Hyrax* unrepresented.

On looking into this question, a very interesting asymmetry of the parts in the adult specimen which I dissected revealed itself. The only previous mention of a muscle at all occupying the position of the stylo-hyoideus major is the casual one by Murie and Mivart of a 'long narrow slip,' the insertion of which they were unable to ascertain, and which they took to be the stylo-pharyngeus. They met with it only on the left side. In my specimen it was present on both right and left sides (*m.sp.*, fig. 2); but while on the right it was alone inserted into the pharyngeal wall by means of a delicate tendon passing between the constrictors of the pharynx, on the left it sent in

¹ George, *loc. cit.*, p. 104. I find that this muscle, like its homologue in the rabbit, is double throughout its fleshy region.

² Murie and Mivart, *Proc. Zool. Soc.*, 1865, p. 330.

addition a long and delicate tendon to the postero-dorsal border of the so-called 'cerato-hyal.'

In its general disposition this muscle thus combines the characters of the stylo-hyoideus major and the stylo-pharyngeus of other mammals, and, like the first-named in *Lepus*, it arises internally to the supposed styloid bone and the other related muscles, in a manner repetitional of that in which (*cf.* fig. 1) the stylo-hyoideus minor stands related to the paroccipital process and the digastric.

There being thus recognisable a fundamental similarity of relationship between the supposed 'styloid' element with the adjacent paroccipital process and the muscles arising from these structures in *Lepus* and *Hyrax*, the detailed differences between the two animals might well have resulted from diversity of modification of the upper portion of the hyoid arch—if proof be forthcoming that their 'styloid' represents that.

Our knowledge of the mammalian hyoid has known no extension greater than that arising out of the discovery by Flower¹ that the 'apophysis styloide du temporal'² (*h.t.*, fig. 4) is the upper element of its anterior cornu. With this, the anterior cornu of the mammalian hyoid, being proved to consist when fully differentiated of four pieces, has been brought into harmony with that of the Ichthyopsida—its upper element (Flower's tympano-hyal) answering to the pharyngo-hyal, its stylo-hyal to the epi-hyal, and its two remaining segments to the cerato- and hypo-hyal in order of enumeration.³

With these thoughts in mind, I lost no opportunity of dissecting the heads of mammals which might help to solve the question, and in course of time the head of a long-eared fox (*Otocyon*), destined for the maceration chamber, gave me an important clue. The anterior cornu of the hyoid of this animal, like that

¹ Flower, *loc. cit.*, Edit. 1, p. 123.

² Still so called by certain French writers, and confused with the stylo-hyal (*ex.* R. Perrier, *Elem. d'Anat. Comp.*, Paris, 1893, p. 915).

³ This being so, it is very unfortunate that in most works on mammalian osteology the terms cerato- and epi-hyal should be still misapplied; Owen, Flower, Parker (in his earlier writings) being followed in this respect by the many text-book writers terming the hypo-hyal the cerato-hyal, and the latter the epi-hyal.

of the dog, consists of three pieces, each fully ossified and in immediate apposition with its fellow. The upper one (*h.s.*, fig. 7) is continuous with a well-marked tract of cartilage (*sy.*), which disappears within the lip of the stylo-mastoid foramen (*fo.*) and may be termed, in accordance with its relationships, the *tympano-styloid synchondrosis*. The skull of *Otocyon* differs from that of the ordinary Canidæ in nothing more conspicuously than the simple non-expanded character of its paroccipital process (*p.o.*, fig. 7). The synchondrosial cartilage (*sy.*) is throughout its whole length closely applied to this, and, crossing its ventral border, it brings the head of the styloid (*h.s.*) into feeble articulation with its lower extremity, in a manner strikingly suggestive of that of the rabbit (fig. 1). Ossify this synchondrosis, and a condition of the 'styloid' fundamentally indistinguishable from that of *Hyrax* (fig. 2) would result; remove it, and one indistinguishable from that of *Lepus* would be brought about.

It is thus clear by comparison, that in both *Hyrax* and the rabbit the hyoid arch has become suppressed throughout its middle region, that we are dealing in Brandt's 'pyramidal ossicle' and the associated skeletal elements with its metamorphosed upper moiety, and in Krause's 'styloid process' with the homologue of the structure originally so-termed in man. With this, interest centres in the anomalous position and relationships of the latter—*i.e.*, its disposition in the rabbit and *Otocyon* caudad of the stylo-mastoid foramen.

On first examination, the supposed 'styloid' of *Hyrax* (*hy.*, fig. 2), except for its great extension upwards, would appear to represent the undoubted styloid (*h.s.*, fig. 1) of *Lepus*; but careful comparison undermines this conclusion. In *Lepus* the styloid is wholly osseous, and its transversely enlarged head is received into a well-marked facet on the correspondingly enlarged extremity of the paroccipital process (*p.o.*). In *Hyrax* the articulation, as already shown (*antea*, p. 515), is of a totally different order. On removing the supposed 'styloid' of this animal and submitting it to microscopic examination, I was not a little surprised to find (fig. 3) that it had a complex structure, and consisted of a greater upper portion (*h.t.*?) which is wholly osseous and a lesser lower one in which a small nodule of bone (*h.s.*?) lay buried.

Comparison of a young *H. syriacus* (total length, 14 c.mm.), in which the paroccipital process is wholly unossified, showed this 'styloid' to be represented by a simple cartilaginous rod—wherefore it follows that one of two interpretations must be put upon the condition of the parts in the animal herein figured (fig. 3). Either the upper element must represent the stylo-hyal and the lower a vestigial cerato-hyal, or the lower a vestigial stylo-hyal and the upper the tympano-hyal of Flower.

The tympano-hyal, as ordinarily understood, lies wholly or in part within the stylo-mastoid foramen. Inasmuch as no traces of a bony element are to be found within the latter in *Hyrax*, I incline to the first of the foregoing interpretations, and regard the unossified area (*sy.*) as the homologue of the tympano-styloid synchondrosis of other mammalia (*cf.* figs. 4 and 7).¹ Whichever be the correct interpretation, the condition of the parts is novel: if the former be justified, in the independence of its assumed tympano-hyal the hyoid of *Hyrax* is unique for that of all known mammals; if the latter, in the extension of its supposed styloid to the lip of the stylo-mastoid foramen it presents a condition unknown elsewhere. Nasonow is now investigating the development of this interesting animal,² and it is to be hoped that he will clear up the point.

In its susceptibility to secondary adaptive modification the hyoid is the most variable of the visceral skeletal arches, and nothing more remarkable in its way could be imagined than the change undergone by it in, say, the Tenuirostres, Humming Birds, and certain Parrots.³ With respect to its anterior cornu, however, the condition of ossification throughout uniformly recurrent areas, and of inconstancy in relationship of its upper extremity to the ot-occipital bones, with accompanying suppression of its middle portion, are features peculiarly mammalian. And when this is sufficiently appreciated, it becomes evident that the conditions exemplified by man (fig. 5) and the rabbit (fig. 1) are

¹ Parker and Bettany asserted (*Morph. of Skull*, p. 302) that the tympano-hyal ossifies from two centres in the sheep, but they unfortunately neither furnished details nor stated the age of the specimen in which this observation was made. I have attempted in vain to confirm it.

² Nasonow; *cf.* *Zool. Anz.*, Bd. xviii. p. 459.

³ *Cf.* Gadow, *Proc. Zool. Soc.*, 1883, p. 62; Lucas, *Proc. U.S. Nat. Mus.*, vol. xiv. p. 169, and Mivart, *Proc. Zool. Soc.*, 1895, p. 162.

expressive of the culminating points in opposite lines of modification. Under the loss of individuality¹ of the tympano-hyal and tympano-styloid synchondrosis (*ht.* and *sy.* of figs. 4 and 7), the stylo-hyal has taken on secondary relationships; but while in man (*h.s.*, fig. 5) it has become co-ossified with the tympanic and disposed cephalad of the stylo-mastoid foramen (*fo.*), in the rabbit (*h.s.*, fig. 1) it has become articulated, or rarely, as in fig. 8, co-ossified² with the exoccipital and disposed caudad of the foramen. To these diversely modified conditions, the terms *protrematic* and *opisthotrematic* may be conveniently applied.³

On taking a broad survey of the mammalian class, with a view of determining the types of which the foregoing are the extremely modified representatives, I found that an interesting condition of the hyoid exemplified in the two-toed sloth (*Cholæpus didactylus*) had been overlooked.

The tympano-hyal element in its most marked form, as originally described by Flower, consists (ex *Ovis*, *h.t.*, fig. 4) of a considerable bone, ankylosed at its base to the periotic and lying wholly in front of the stylo-mastoid foramen (*fo.*) largely embedded in the tympanic.⁴ When thus highly developed, it is usually connected with the styloid by means of a massive synchondrosis (*sy.*). As in man, the styloid lies wholly in front of the styloid-mastoid foramen; and, in consideration of this and the further differences between the two, precision may be given to our ideas by the application of the term *integro-cornuate* to the type represented by the sheep, in which the anterior cornu

¹ I use these words in consideration of the differences of interpretation still put upon the human 'styloid process.' While there can be little doubt that in the rabbit the tympano-hyal and tympano-styloid synchondrosis are suppressed, and that in man the styloid process is at least a compound of the tympano- and stylo-hyal as pointed out by Flower (*loc. cit.*, edit. 2, p. 159), Thomas has attempted to show (*Élem. d'Ostéologie*, Paris, 1865, p. 219) that the cerato-hyal (epi-hyal auct.) is normally incorporated in it. Like Wortman (*Mem. Nat. Acad. Sci. Washington*, vol. vi. p. 203), I have endeavoured in vain to confirm Thomas's observation.

² It is interesting to note in this connection that, conversely, in man (according to Parker and Bettany, *Morph. of Skull*, p. 308) the stylo-hyal may remain unankylosed even to middle life.

³ A styloid process is customarily accorded to man and the marmosets alone among primates; but I am strongly under the impression that the stylo-, if not the tympano-hyal element also is represented among the Cercopithecidae and Simiidae. Cf. also Parker and Bettany, *Morph. of Skull*, p. 308.

⁴ Cf. Flower, *loc. cit.*, Edit. 1, pp. 123 and 169.

is complete, and *discreto-cornuate* to that represented by man, in which it is largely suppressed.

That the two are modifications of a common type is certain. In man we have to deal with a discreto-cornuate *protrematic* condition, as compared with an integro-cornuate protrematic of the sheep and most other ruminantia.¹ In a consistent terminology, the condition exemplified by the rabbit (fig. 1) should accordingly be termed the discreto-cornuate *opisthotrematic*, and the question naturally arises whether an integro-cornuate opisthotrematic state may not exist in some placentalia.

It was in the pursuit of this that my interest became excited by the study of the two-toed sloth.

The tympano-hyal, despite its morphological importance, has received very little attention from recent writers. For example, Leche,² in Bronn's 'Thier-Reich,' deals with it very insufficiently, according it categorically to the pig, whalebone whale, and the primates, but not even mentioning its existence among ruminants, in which it attains its greatest known development.

In all cases hitherto described, the tympano-hyal slopes obliquely forwards (ex Sheep, *h.t.*, fig. 4) and outwards, or perhaps a little backwards (ex *Cryptoprocta*, and, less conspicuously, *Canis* and *Phocaena*). In *Cholæpus*, however, it slopes obliquely backwards and downwards (*h.t.*, fig. 6), and, in virtue of its ankylosis to the periotic and its enormous size, it assumes a position the precise converse of that seen in the ruminant (*cf.* fig. 4). The rest of the anterior cornu of the hyoid in this animal consists of a couple of stout bones, the upper of which (*h.s.*), in giving origin to the stylo-glossus muscle (*m.sg.*),³ would appear to be the stylo-hyal. Its head, unlike that of the styloid of any other mammal, develops an immense condyle, which, as indicated in the accompanying figure, is received into a corre-

¹ Not in all, however; *cf. infra*, p. 523.

² Leche, Bronn's *Klass. und Ordng. d. Thier.-Reichs*, Bd. 6, Abth. v. pp. 636-639. I am at a loss to find evidence for the supposed origin of the 'epi-hyal' by ossification of the cornual ligament.

³ Mackintosh (*Proc. R. Irish Acad.*, ser. ii. vol. ii., Sci., p. 69) describes this muscle as arising from the 'cerato-hyal' and the digastric as arising from the 'stylo-hyal.' Assuming that by the latter term he refers to the element which I have so named, there can be no question that in my specimen the two muscles arise from it on each side, as delineated in fig. 6.

sponding depression of the cranial wall occupying the interspace between the paroccipital and mastoid processes (*p.o.*, *p m.*). This most remarkable condition is accompanied, among other things, by the loss of connection between the digastric muscle (*m.d.*) and the exoccipital bone, and the development of special fibres in the hyo-occipito-mastoid region.

When it is remembered that in this animal the anterior cornu of the hyoid is completely ossified, comparison with the protrematic integro-cornuate type (fig. 4) gives us a conversely constituted opisthotrematic integro-cornuate; and consequently it might appear that the condition of backward rotation in the rabbit (fig. 1) may be related to that in the sloth (fig. 6) somewhat similarly to that in which the condition of forward rotation in man (fig. 5) may be related to that in, say, the sheep (fig. 4)—*Otocyon* (fig. 7) apparently furnishing an intermediate stage in the former series.

It becomes thus a question of inter-relationship between the pro- and opistho-trematic types, *i.e.*, are the conditions represented by the sheep and the sloth those from which, by advancing parallelism of modification, the culminating states met with in man and the rabbit have been derived?

According to Parker,¹ a pro-trematic stage is apparently followed by an opistho-trematic in the developing pig. In the puppy, in which the paroccipital process is as yet inexpansive, the tympano-styloid synchondrosis is backwardly rotated, so that the styloid is brought into close relationship with it—*i.e.*, a pro-trematic stage is here *preceded* by a partially opistho-trematic. Whereas in man the styloid is situated far forwards, in front of the stylo-mastoid foramen; in some of the apes (*Cercopithecidae*) a condition exists which appears to me strikingly suggestive of the presence of a reduced styloid, in a position of backward and inward rotation and approximation to the exoccipital region. And if the recent observations of Zondek² on the first differentiation of the hyoid arch in the rabbit are correct, there can be little doubt that in that animal the opistho-trematic condition is secondary. Again, while the pro-trematic integro-cornuate condition, with accompanying maximum development of the

¹ Parker, *Phil. Trans.*, 1874, part i., *cf.* pl. 34, fig. i., and 36, fig. ii.

² Zondek, *Archiv. f. Mikr. Anat.*, Bd. 44, p. 501.

tympano-hyal, is generally characteristic of the Ruminantia, examination of the rich material stored in our National Museum has shown that in closely allied members of that group reduction amounting to loss of all visible traces of this element may occur—for example, among the antelopes, while in *Nanotragus Haggardi* the tympano-hyal is large, and in *N. moschatus* it is reduced under advancing overgrowth of the bulla, in *Madogna Phillippsi* it is non-recognisable externally.¹

Under these circumstances, all that can definitely be asserted is that the types which I have herein defined exist, and that extreme conditions of modification are accompanied by suppression more or less complete of the upper (pharyngo- or tympano-hyal) element and the tympano-styloid synchondrosis, with resulting displacement of the epi-(stylo) hyal. The typically opisthotrematic condition, at present known only for certain in the rabbit, is suggested for the Cetacea by the grooving of the exoccipital in the young state for the reception of the tympano-styloid synchondrosis, and by Flower's observation² that "a strong ligamentous attachment" exists between the stylo-hyal and the paroccipital process in the dolphins, and for the Sirenia by his remark (*loc. cit.*, p. 202) that in *Manatus australis* the stylo-hyal is attached by a short ligament "chiefly to the exoccipital."

That the mere elongation of the paroccipital process has little if anything to do with the changes primarily undergone is certain, on comparison say of *Cryptoprocta* with *Canis*, or *Tapirus* with *Lepus*. That extensive development of the tympano-hyal is associated with mere apposition and downgrowth of the exoccipital and squamosal, such as occurs in the Perissodactyla, is disproved on comparison of *Ovis* and *Hyæmoschus*. As Flower has pointed out, when the tympano-hyal is small a fibro-cartilaginous tract connects it with the stylo-hyal, and when the former is large the synchondrosis is usually short. This justifies the conclusion that small size of the epi-(stylo) hyal is usually associated with the reduction of the pharyngo-(tympano) hyal.

¹ The conditions suggest reduction proportionate to the inflation of the bulla. For the privilege of examining these skulls I am indebted to the courtesy of Sir W. Flower.

² Flower, *loc. cit.*, Edit. 1, p. 190.

Beyond this it is impossible to go morphologically. For every handful of skulls compared on a purely morphological basis, theories may be formulated which the next handful will overthrow. The explanation of the facts must unquestionably be sought in physiological investigation.

Comparison of *Otocyon* (fig. 7) with *Canis*, of *Cynocephalus* with *Homo*, suggests that the opposite extremes of modification may be realised by closely related forms; and as interest so largely centres in the common rabbit, comparison of other rodents is invited. The close approximation of the paroccipital and mastoid processes and the expansion of the extremity of the former, occur in such genera as *Arvicola*, *Cricetomys*, *Fiber*, *Hydromys*, *Microtus*, *Neostoma*, and in several *Muridæ*, and thus suggest a wide realisation of the opisthotrematic condition for the rodent order. On the other hand, in the beaver the stylo-hyal is very well developed, complete, and situated well forwards. It seems hard to conceive that the detailed condition and relationships of the upper portion of the hyoid should be the same in genera like *Cavia*, *Chinchilla*, *Myopotamus*; and one is tempted to inquire whether, in respect to the anterior cornu of the hyoid, the enormous order Rodentia may not exhaust the conditions occurring throughout the class Mammalia, as Robinson's investigations show to be the case¹ with the mouth of the Fallopian tube.

In consideration of the view that the body of the mammalian hyoid may possibly represent the basal elements (copulæ) of two post-oral visceral arches, I have long been on the alert for evidence of a double origin. Thanks to the acumen of my demonstrator, Mr M. F. Woodward, I have lately come into possession of the rabbit's hyoid delineated in figs. 9 and 10.

Unlike that of any mammal hitherto described, it is subdivided by a transverse suture (*s.h.*) into two wholly distinct and fairly equal portions, inequality being chiefly due to the forward growth of the hinder half, to furnish (*cf.* fig. 10) a process for attachment of the mylo-hyoid muscle. Interest attaches to the specimen beyond this, as it was obtained from an individual of from 3–4 weeks, the age at which the cotyloid

¹ Robinson, *Journ. Anat. and Phys.*, vol. xxi. p. 169.

element of the hip-girdle and the true coracoid (metacoracoid) of the shoulder-girdle, which as distinct structures are of short duration, become evident.¹

On examining a series of specimens of different ages, however, in the hope that the suture might be constant, I was doomed to disappointment. In a three weeks animal, in which the anterior cornua were still wholly cartilaginous, I found that the region of the transverse suture was occupied by a tract of cartilage, and that a similar cartilaginous area extended backwards in the median line, in a manner indicative of ossification from three centres, having the limitations of the chondrites, which, by union, give rise to the body of the hyoid in certain anurous amphibia, and were interpreted by Parker as 'basi- and hyo-(hypo) branchials' (the 'copula' and 'planum branchiale' of Gaupp).² Hope was, however, shattered, by the fact that in a three days animal the body of the hyoid was found to be superficially continuously ossified; and it must remain for future investigation to show whether the condition of the undoubtedly interesting specimen herein figured is more than variational.

EXPLANATION OF PLATE VIII.

Fig. 1. *Lepus cuniculus*.—Peritympanic region of skull, dissected to show the relationships of the mastoid and paroccipital processes with the styloid and associated muscles. $\times 1\frac{1}{2}$.

Fig. 2. *Hyrax capensis*.—Companion dissection to fig. 1—the styloglossus and digastric muscles displaced to show the stylo-pharyngeus (*m.sp.*). $\times 1\frac{1}{2}$.

Fig. 3. *Hyrax capensis*.—Lateral view of the paroccipital and mastoid processes and upper extremity of the hyoid arch, after separation. $\times 1\frac{1}{2}$.

Fig. 4. Sheep (*Ovis aries*).—Lateral view of the peritympanic region of the left side, to show the relationships of the upper extremity of the hyoid arch. Young specimen. Nat. size.

Fig. 5. Peritympanic region of human skull (Galla), with a well-developed styloid process. Nat. size.

Fig. 6. Two-toed sloth (*Choloepus didactylus*).—Companion dissec-

¹ Cf. Krause, *M. Internat. Jour. Anat. and Hist.*, vol. ii. p. 159, and also *Proc. Zool. Soc.*, 1893, p. 589.

² Cf. Parker, *Phil. Trans.*, 1881, part i.; and Gaupp, in Schwalbe's *Morpholg. Arbeiten*, Bd. 3, p. 399.

tion to fig. 4, with the heads of the stylo-glossus and digastric muscles. Nat. size.

Fig. 7. Long-eared fox (*Otocyon megalotis*).—Companion dissection to figs. 4 and 6. Nat. size.

Fig. 8. *Lepus cuniculus*.—Specimen showing co-ossification of the stylo-hyal and paroccipital process. $\times 1\frac{1}{2}$.

Fig. 9. *Lepus cuniculus*.—Hyoid of a three to four weeks individual, showing median transverse suture of the body. Seen from above.

Fig. 10. The same, seen from beneath. $\times 2$.

REFERENCE LETTERS.

cr. xii.—hypoglossus nerve.

fo.—stylo-mastoid foramen.

h.s.—stylo-hyal (in fig. 5, the styloid process).

h.t.—tympano-hyal.

h.th.—thyro-hyal.

hy.—upper extremity of hyoid arch.

m.d.—digastric muscle.

m.s'.—m. stylo-hyoideus major.

m.s''.—m. stylo-hyoideus minor.

m.sg.—m. stylo-glossus.

m.sp.—m. stylo-pharyngeus.

p.m.—mastoid process.

p.o.—paroccipital process.

s.h.—transverse suture of body of hyoid.

s.m.—occipito-mastoid suture.

sy.—tympano-styloid synchondrosis.

tp.—tympanic bone.

OCCURRENCE OF AN ENORMOUS RENAL CALCULUS.

By J. B. YEOMAN, M.B., *Demonstrator of Anatomy, University of Edinburgh.*

THE following is an account of the condition of the kidneys, with a description of an unusually large renal calculus, found in a subject in the University Dissecting-rooms, in June 1896. The subject was an elderly man, whose age was ascertained to be between sixty-four and seventy, but could not be more accurately determined.

Right Kidney.—The ascending colon and third part of the duodenum lay in front of the right kidney. All the viscera practically occupied their normal positions. Attention was attracted by a large hard mass behind the ascending colon. The colon having been turned aside, the mass was found to be in association with the kidney. An incision was made into it and a hard yellowish-white calculus was exposed. This was removed by an incision some 4 inches in length. The kidney and ureter were next removed, and the incision was found to have merely passed through a dilated renal pelvis. A lymphatic gland $1\frac{1}{4}$ inches long and $\frac{1}{2}$ inch broad lay in front of the structures entering the hilum. On section of the vessels at the hilum the renal vein appeared to be unusually short, but on closer examination this was ascertained to be due to the fact that the sinus was filled by a large mass of dense fatty tissue which closely invested the renal vein, renal artery, and ureter.

Measurements of kidney:—The kidney measured

7 $\frac{1}{2}$ inches in length.

4 inches in breadth at the hilum.

2 inches in thickness at the posterior border.

The distended pelvis was 4 inches in length and 2 inches in breadth from the anterior lip of the sinus.

Towards the upper end of the kidney, on the anterior surface, there was a cyst about the size of a pea. The capsule stripped readily off, and was non-adherent. The general surface was lobu-

lated, the lobulations being due to the occupation of the calices by projections from the calculus. The kidney substance around these lobulations appeared, for the most part, to be normal in structure, so far as could be judged from a naked-eye examination. Where it was normal it measured $\frac{3}{4}$ -inch in thickness on section, whilst in the lobulations it was thinned down so as to form a mere cyst-like wall.

Calculus.—The calculus was an exact cast of the interior of the pelvis, calices, and infundibula. It was of a yellowish-white colour, and stained red over certain portions.

The weight was 552 grammes (about 1 lb. 4 oz. avoirdupois). The longest diameter measured $4\frac{1}{2}$ inches; breadth, 5 inches; circumference around its most prominent projections, $10\frac{1}{2}$ inches.

It showed a large pear-shaped portion, which had evidently occupied the pelvis. The remaining part presented seven projections, which had lain in the infundibula and calices. Each projection was attached to the general mass by a constricted neck, and beyond the neck expanded so as to end in a flat surface. From an examination of the broken end of one of these projections, the interior was seen to consist of a multitude of grains, each rather larger than a pin's head, agglutinated together.

Chemical Composition.—Particles were removed from the interior of the broken projection, and also from its edge. These were subjected to a qualitative analysis.

1. *Particles from Interior.*—These were insoluble in hydrochloric acid, even when concentrated, thus excluding phosphates, oxalates, and carbonates.

Concentrated ammonia did not affect them, so that tyrosin, xanthin, and cystin were all absent.

On boiling with caustic potash no ammonia was given off, so that ammonium urate and ammonio-magnesium phosphate were not constituents.

On adding dilute nitric acid and evaporating to dryness the residuum gave a purple-red colour with ammonia, and a blue-violet with caustic potash, proving the presence of uric acid.

2. *Particles from Exterior of Projection.*—On the addition of hydrochloric acid some carbonic acid gas was given off, indicating the presence of a carbonate.

Faint traces of magnesium were made out to be present. On the addition of heat to the particles they charred very readily, indicating that organic matter was present in large quantity.

The ash, as well as the hydrochloric acid extract obtained from the particles, was exceedingly rich in phosphorus.

Everything in connection with the behaviour of this organic matter indicated that it was of nuclear origin, and in all probability derived from dried pus.

Left Kidney.—The left kidney occupied its normal position. Comparatively small calculi could be felt embedded in its substance, and also free in the pelvis. When dissected out, the kidney measured 6 inches in length, $2\frac{1}{2}$ inches in breadth at the hilum, and $\frac{3}{4}$ inch in thickness at the posterior border. The pelvis was widely dilated, although not to the same extent as in the right kidney. The capsule stripped readily off, and the kidney substance appeared normal. A plaster-cast was taken of the pelvis and calices, and this bore a striking resemblance in form, but was somewhat smaller than the calculus removed from the right kidney.

Calculi.—Of the four calculi removed from this kidney the largest was about the size of a horse-bean, and of somewhat the same shape. It weighed 4·7 grammes. The next in size weighed 1·85 grammes. These two lay free in the pelvis, and the smaller was distinctly facettèd.

Of the two embedded in the kidney substance one was tooth-shaped, 1 cm. in length, and 4 mm. in breadth at its base. It weighed ·15 grammes. The other was pyramidal, with a concave oval facet on its base. It was 3 mm. in length from apex to base, and weighed ·02 grammes. On one of its flat surfaces there were two or three minute projections.

The sigmoid flexure in this subject measured 17 inches in length.

I owe my thanks to T. H. Milroy, M.B., B.Sc., for assistance in the analysis of the large calculus.

A DISCUSSION OF SOME POINTS IN THE DISTRIBUTION OF THE SPINAL NERVES. By Professor A. M. PATERSON, *University College, Liverpool.*

A Typical Spinal Nerve.

It is not necessary to do more than indicate the orderly segmental manner of distribution of a typical spinal (thoracic) nerve. Its posterior, lateral and anterior divisions have all their definite areas of distribution to the muscles and skin in the dorsum, side, and venter of the trunk.

The special difficulties which arise in relation to the distribution of the spinal nerves are (1) the homologies, and (2) the segmental distribution of the limb nerves.

I. HOMOLOGIES OF LIMB NERVES.

Our President has recently expressed (Quain, vol. iii. p. 382) the different views held on this question:—Are the limb nerves homologous with the lateral branches, or with the entire anterior primary divisions of thoracic nerves?

The outstanding facts in favour of the latter view are (1) the absence of anterior cutaneous nerves to the trunk in the limb regions; (2) the division of the nerves entering the limb plexuses into posterior and anterior divisions, comparable to the lateral and anterior branches of a thoracic nerve. The main objections to the view are (1) the apparent anomalies in the arrangement of some of the limb nerves, (2) the presence of an intercostal branch to the first thoracic, and (3) the behaviour of T2 and S3.

These difficulties admittedly prevent an unconditional acceptance of the view I uphold. They are obstacles which apply equally to both limbs; and specially occur in nerves supplying the parts on the post-axial border.

1. In both limb plexuses the most post-axial nerve fails to divide, and is entirely associated with the anterior (ventral) cord.

(In the brachial plexus, Herringham traced T1 to the posterior

cord 6 times out of 45. I have recently found the connection in 11 cases out of 33.)

2. In both limbs the post-axial border is supplied by a nerve (T2 or S3) which in other respects is scarcely to be regarded as a limb nerve proper.

3. In the lower limb the last thoracic nerve, the first lumbar nerve, and the third sacral nerve supply branches to the *dorsal* surface of the limb (=lateral branches), and branches to the trunk reaching the ventral axis of the body (=anterior branches), but no (cutaneous) branches to the ventral aspect of the limb (exc. L1).

How are we to account for the absence of the posterior element in the limb plexuses of T1 and of S2 or S3? And what light do these other nerves, intercosto-humeral, T12, L1, and small sciatic throw upon the question of homology of limb nerves?

Agreeing at the outset that the dorsal and ventral surfaces of each limb are homologous, and correspond to the lateral and ventral surfaces of the trunk, there are certain anomalies present preventing us from understanding the homology of the dorsal and ventral trunks in the limb plexuses with the lateral and ventral trunks of the spinal nerves,—anomalies in origin and in distribution.

These anomalies exist chiefly at the post-axial border of each limb, and assist, I think, in throwing light upon the conditions.

In the Arm, at the post-axial border, the dorsal branch of the ulnar, the posterior branch of the internal cutaneous, the lesser internal cutaneous, and the intercosto-humeral nerves, are distributed in series with one another on the posterior (dorsal) side of the limb. Is it unjustifiable to suppose that the two first-named nerves contain the posterior (dorsal) element of T1, which, instead of leaving the nerve in the axilla in the ordinary way, has been drawn into the limb by the close connection of C8 and T1, and for convenience of transit along the post-axial border of the limb?

The lesser internal cutaneous arises only from T1 (Herringham); and I have frequently followed it up to the dorsal aspect of the nerve in the plexus.

It is not necessary to dilate upon the variability in mode of distribution of T2. Cunningham mentions it as frequently assist-

ing in supplying the intercostal muscles of the first space. Its connection with T1 in the plexus I hope to refer to on another occasion. All I wish to insist upon just now is, that the lateral branch is distributed on the post-axial border *and dorsal surface* of the arm. I venture to suggest that the nerves named are in series with the posterior trunks of the brachial plexus. In the case of the first three they contain the missing posterior part of T1 (there are no muscles on the back of the arm supplied by T1); and the humeral nerve from T2 is homologous with them. The inference, therefore, is that the anterior branch of T2 is homologous with the anterior (ventral) cords of the brachial plexus.

In the lower limb, there are nerves which aid in this inquiry at both borders. *At the preaxial border*: T12, by its iliac branch, assists in supplying the dorsal aspect of the limb. L1, by the iliac branch of the ilio-hypogastric, also helps in supplying the same surface. The anterior terminal branch of T12 is limited wholly to the trunk; the ilio-hypogastric and ilio-inguinal supply the trunk, and the latter reaches also the ventral surface of the limb. Again, although here no limb muscles are innervated by these nerves, their cutaneous parts indicate a similar homology to that referred to above. *At the post-axial border*, at the origin of the sacral plexus, it is usual for the internal popliteal nerve to contain a nerve more post-axial than the last entering the external popliteal. In the limb, the external saphenous nerve, or one of its components (Com. Tib. or Com. Fib.), supplies the outer side of the leg and foot, very often extending for a considerable distance on to the dorsum. The area in question is supplied by S1, 2, 3, or S1, 2. Higher up the limb this (post-axial) border receives the small sciatic (S2 3, or S1, 2, 3). These nerves may not unfairly be considered to contain the missing element in the formation of the plexus, completing the dorsal or posterior part of the last nerve (S2 or S3).

The variability in the constitution of the external saphenous nerve supports this view. When the dorsum of the foot and post-axial border of the leg are supplied by the communis tibialis nerve alone it may be considered that the nerve has passed down the limb in a way similar to that indicated for the dorsal branch of the ulnar.

It is not necessary here to discuss the homologies of the small sciatic nerve, beyond stating the opinion that its gluteal and femoral branches correspond to lateral, and its internal femoral and perineal branches to anterior divisions of typical nerves. It is only with the share taken in the formation of this nerve by S3 that we are concerned just now. Even when that nerve is not concerned in forming the internal popliteal it is distributed through the small sciatic (1) to the dorsal aspect of the limb, buttock and thigh, and (2) to the perineum. The former is the lateral, the latter homologous with the anterior branch of the third sacral nerve. The anomalous nerves mentioned appear to support the view that the limb nerves are homologous with the whole anterior divisions of typical thoracic nerves.

II. THE SEGMENTAL DISTRIBUTION OF LIMB NERVES.

The arrangement of the limb nerves in plexuses, and the fact that in the limbs no spot of skin, and (probably) no muscle, is supplied by one spinal nerve alone, make it impossible to state with precision the segmental distribution of the spinal nerves in the limbs. Although, however, by anatomical methods it is impossible to separate the fibres of one spinal nerve from its neighbour, yet there is sufficient evidence to indicate on the whole a distinctly continuous segmental mode of distribution of both motor and sensory fibres.

A different plan or scheme obtains for muscles and for skin.

A. *Muscles.*

1. No limb muscle proper receives its nerve supply from posterior primary divisions.

2. The limb muscles are fundamentally divisible into dorsal and ventral strata supplied by dorsal and ventral nerves of the plexuses; and dorsal muscles and ventral muscles are always supplied by their corresponding nerves. A double nerve supply usually occurs at the borders of the limb (*e.g.*, pectineus, biceps flexor cruris, brachialis anticus), and indicates a fusion of dorsal and ventral elements.

3. The muscular stratum is more extensive on the ventral than on the dorsal surface of each limb; and the ventral nerves are more numerous. The nerve added is post-axially placed.

	<i>Dorsal Nerves.</i>	<i>Ventral Nerves.</i>
<i>Arm</i>	C. (3, 4), 5, 6, 7, 8.	C. 5, 6, 7, 8, T. 1.
<i>Lower Limb</i>	L. 2, 3, 4, 5, S. 1, 2.	L. 2, 3, 4, 5, S. 1, 2, 3.

Tracing the nerves to the periphery, those centrally placed extend furthest; the pre-axial and post-axial nerves on both surfaces in each limb only supplying the more proximal parts of the limb.

In the Arm.

On the dorsal surface : Shoulder muscles, C. 3, 4, 5, 6, 7, 8.
Arm muscles, C. 6, 7, 8.
Forearm muscles, C. 6, 7.

On the ventral surface : Chest muscles, C. 5, 6, 7, 8, T. 1.
Arm muscles, C. 5, 6, 7.
Forearm muscles, C. 6, 7, 8, T. 1.
Hand muscles, C. 6, 7, 8, (T. 1).

Dorsum.

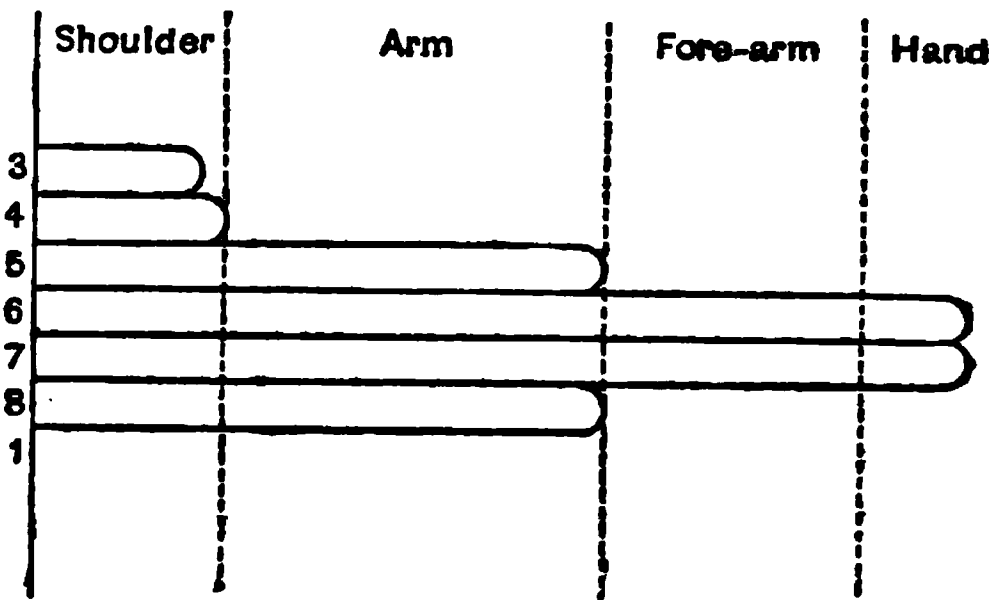


FIG. 1.

Venter.

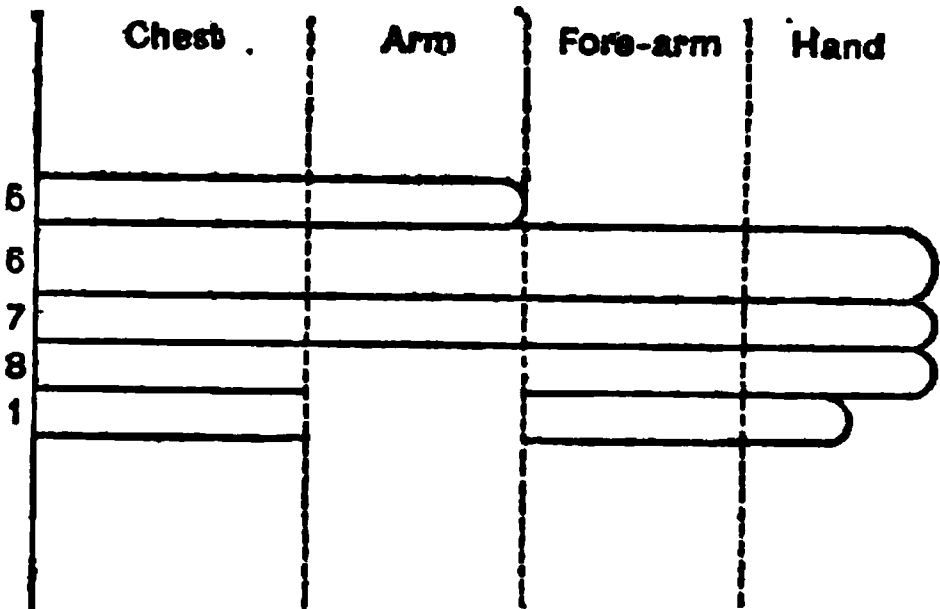


FIG. 2.

The diagram (fig. 2) indicates a distinct hiatus in the continuous and segmental distribution of the nerves in the front of the arm. While by stretching a point the C. 6 may be regarded as continuously supplying a ray right through to the hand at the preaxial border on the dorsal surface (it does not do so really, as there is a gap between deltoid and supinator longus), there is a marked gap at the post-axial border on the ventral surface. C. 8 and T. 1 absolutely disappear on the inner side of the arm, and only reappear in the forearm. This may perhaps be attributed to muscular suppression; the cutaneous innervation of the area makes the segment complete.

In the Lower Limb.

On the dorsal surface: Thigh and buttock, L2 3 4 5, S1, 2.

Leg and foot, L4, 5, S1.

On the ventral surface: Thigh, L2, 3, 4, 5, S1, 2, 3.

Leg, L4, 5, S1, 2.

Foot, L5, S1, 2.

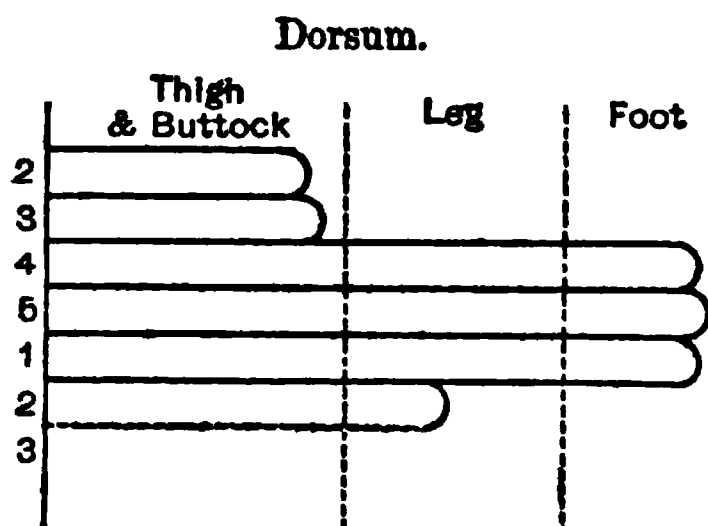


FIG. 3.

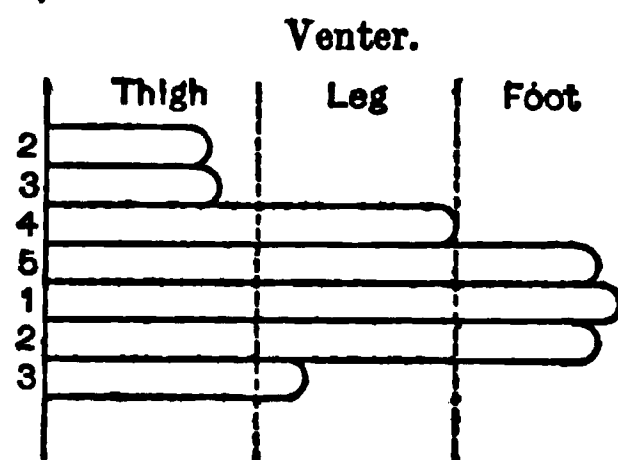


FIG. 4.

In the leg there are no anomalous gaps. The points noticeable are that (1) on the whole the ventral nerves are more post-axial, *e.g.*, L4, 5, S1 appear on the dorsum of the foot; on the sole, L5, S1, 2. (2) the ventral nerves are more numerous than the dorsal, by the addition of a post-axial nerve S3 (to two muscles, obturator internus and biceps).

There is thus in both limbs a certain agreement in the distribution of the motor nerves.

1. There is, with certain specified exceptions, a continuity in the segmental distribution of motor nerves on both dorsal and ventral surfaces.

2. The dorsal and ventral nerves adhere to their proper areas.

3. There are more nerves implicated on the ventral side.
4. The additional ventral nerves are post-axially placed.
5. While the pre-axial and post-axial nerves are shed in their passage through the limb, the more pre-axial are more proximally lost than the post-axial.

Taking all the evidence at our disposal, I think that while we must discard Herringham's Axioms, II. B. and C. (to the effect that the muscles nearer the long axis of the body, and muscles nearer the surface of the limb, are supplied by higher nerves); his law II. A. possesses a basis of truth. "*Of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve; and that nearer the tail end by the lower nerve.*"

B. Skin.

While in some respects the cutaneous innervation of the limbs agrees with the method of supply to muscles, in others there are such differences that one concludes that a different plan or type underlies the distribution of the limb nerves as far as skin is concerned. The suppression of muscles leads to anomalies in segmental distribution. The cutaneous areas are continuous.

The axial lines of the limbs give the key to a proper understanding of the distribution of cutaneous nerves to the limbs.

Sherrington regards these lines as an extension on to the dorsal and ventral surfaces of the limbs of the axial lines of the trunk. I am rather inclined to regard them as skin territories, which, owing to the absence of their proper segmental nerves which have been carried away for the innervation of the skin areas of the limb proper, have been raided by a series of nerves belonging more strictly to adjacent districts.

These axial lines are very similar in both limbs.

The dorsal axial line

In the arm can be traced from the spine to the lower end of the deltoid. Its presence indicates a gap in the continuity of the cutaneous nerves supplying the limb from its pre-axial to its post-axial border (C4 or 5 to T2). Where it ends, the nerves can be traced in continuity on the dorsal surface of the limb from border to border.

In the leg the dorsal axial line is traceable from the spine over the buttock to the head of the fibula. It separates the

areas of distribution of L3 from S3. At its lower end there is a continuous, segmental, distribution of the cutaneous branches of the spinal nerves from pre-axial to post-axial border of the dorsal surface (L3-S2).

The ventral axial line in both limbs is much more extensive.

In the arm it is traceable from the sternum at the level of the second rib, down the front of the limb to the wrist. It separates successively the cutaneous distribution of C4, 5, 6 from T2, 1, C8. At its lower end, in the palm only is there continuity of cutaneous innervation (C5, 6, 7, 8, T1).

In the lower limb it is traceable from the dorsum of the penis down the inner side and back of thigh and leg to the heel. It separates successively L1, 2, 3, 4, from S3, 2, 1. Only in the sole does L5 appear to complete the segmental and continuous distribution of cutaneous nerves. With the qualification introduced by the presence of these lines, it is obvious how both surfaces of each limb receive a cutaneous nerve supply which is even more obviously segmental than in the case of muscles.

There are certain resemblances and certain differences in the two cases.

Resemblances.

1. Dorsal and ventral surfaces are supplied by dorsal and ventral nerves.

2. The pre-axial and post-axial nerves are shed along the borders of the limbs in their passage to the periphery, the central nerves extending furthest.

3. The pre-axial nerves tend to disappear more proximally than the post-axial nerves.

Differences.

1. The dorsal cutaneous area is much more extensive than the ventral area.

2. The dorsal area is supplied by more numerous nerves:—

<i>Arm</i>	{	<i>Dorsal</i> , C3, 4, 5, 6, 7, 8, T1, 2.	<i>Lower</i>	{	T1 2, L1, 2, 3, 4, 5, S1, 2, 3.
		<i>Ventral</i> , C3 4 5, 6, 7, 8, T1.			<i>limb.</i>	{	L2 3 4 5, S1, 2.

and the added nerves are generally more post-axial.

3. Nerves not properly limb nerves, and derived from both posterior and anterior primary divisions, are brought into requi-

sition for the supply of the skin. This is specially seen at the borders of the limbs.

<i>Arm,</i>	.	pre-axial border, C3, 4.
		post-axial border, T3, 2.
<i>Lower Limb,</i>		pre-axial border, T12, L1.
		post-axial border, S3, 2.

The most marked feature in the cutaneous innervation of the limbs is certainly the absence of gaps; the investigations of Herringham and Sherrington have made abundantly clear the essentially segmental nature of the distribution of the cutaneous nerves.

A CASE OF ADRENAL ADENOMA. By T. N. KELYNACK,
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Owens College.*

ADENOMATA form one of the most important and interesting forms of growth met with in connection with the supra-renal bodies.

As they are by no means of common occurrence, it seems desirable that each case should be placed on record.

The following is the only well-defined adrenal adenoma reaching to any considerable size which has come under my notice, although during the last few years I have had opportunities of examining considerably over a thousand subjects.

The patient (1) was a warehouseman, aged 63. Death was due to cerebral hæmorrhage, which occurred at night during a drunken carouse. The kidneys were typically "granular." An extensive hæmorrhage involved the greater part of the left basal ganglia, ploughed up the internal capsule, and extended into the lateral ventricle. There was no growth anywhere in the body except in the right supra-renal.

The right adrenal was very much enlarged, but uniformly so, and was somewhat triangular in shape. It weighed one and a half ounce. On section it consisted of soft, reddish-white, and extremely vascular-looking tissue.

There was no division into cortex and medulla, the whole body having a more or less uniform appearance.

The left supra-renal was perfectly normal.

Microscopical Examination.

After hardening in alcohol and embedding in celloidin, sections were cut by means of an ether-freezing microtome. The most satisfactory staining was obtained with hæmatin and rubin and orange.

The following briefly indicates structure, as seen under both low and high powers (Zeiss, A and F) :—

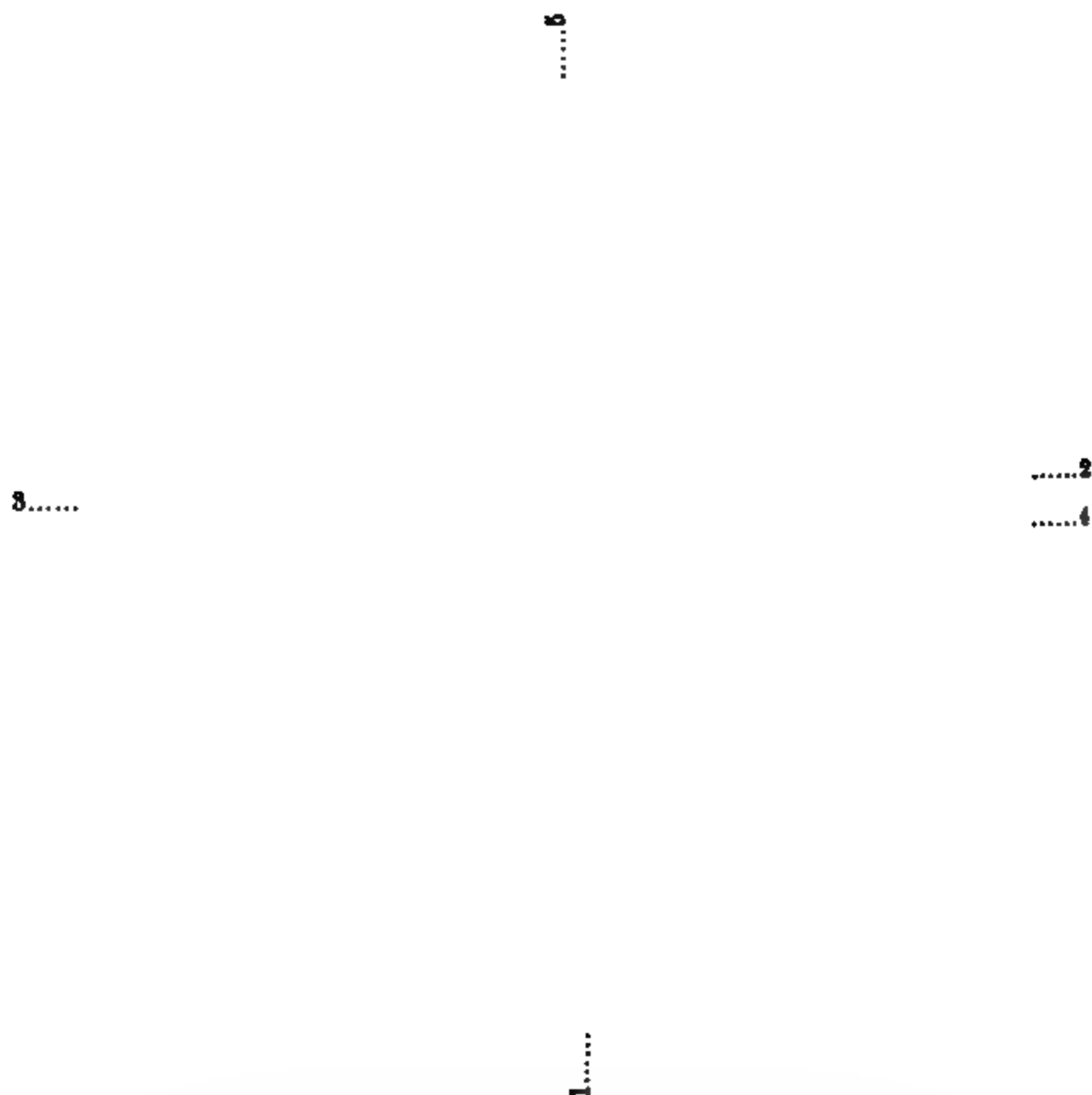


FIG. 1.—Section of Adrenal Adenoma, low power (Zeiss oc. 2, obj. A).—1, Stroma of fine fibrous tissue ; 2, clusters of round cells in the stroma ; 3, spaces lined by and containing cubical epithelial cells ; 4, one cyst-like space shows tendency to intra-cystic papillary growth ; 5, one large space, to the right, shows granular material, consisting in part of degenerated cells.



FIG. 2.—Section of Adrenal Adenoma, high power (Zeiss oc. 2, obj. D).—1, Stroma of fine fibrous tissue; 2, round cells scattered through stroma; 3, irregular spaces lined with epithelium.

Low Power.—

A fibrous *stroma* split up the whole adrenal growth into irregular spaces, containing cells. The fibrous trabeculæ varied much in extent in different parts, being in some places very abundant, and forming large bands of connective tissue, while in other parts consisting of a mere network of fine fibres. In many places the stroma presented aggregations of small round cells, staining deeply with hæmatin.

The *spaces* were very irregular in size and shape. Some were very large, while others were extremely small. Many were more or less circular, but some presented a very distinctly elongated, almost cylindrical, appearance. All the spaces contained masses of *cells*, which in some instances filled the cavity, while in others they formed a lining only. Some of the spaces contained a considerable amount of granular structureless material, consisting apparently in greater part of degenerate cells. In some few places there were collections of blood corpuscles.

High Power.—

The stroma was formed of closely placed fine *fibrous tissue*. The nuclei of the cells were indistinct, and stained badly. The fine trabecular fibres surrounded the groups and columns of epithelial cells, and even passed as it were into the spaces, dividing the larger clusters of cells into smaller group. In some few instances the fibrous tissue projected as papillæ into the cysts, lined with a single layer of epithelial cells. In many places there were extensive collections of round cells, evidently *leucocytes*, and, often in close proximity, yellowish areas of *blood* accumulation.

The *cells* occupying the spaces were of more or less cubical shape, each with a well-defined, large, and deeply staining nucleus. The protoplasm was of a somewhat granular appearance. Many of the cells showed various degrees of degenerative change. Some were quite necrotic, and would not take the stain at all. While the cells lining the spaces varied much in size and shape, they all presented distinct epithelial characters, and were arranged after a clearly adenomatous type.

The spaces were usually lined by a single layer of cells. There was no clearly defined basement membrane; the cells

appeared to be directly planted on the fibrous trabeculae. In many instances there were two or more rows of cells, and sometimes whole spaces were crowded with cells. Some spaces showed slight evidence of intra-cystic papillomatous growth. In some places the cells were arranged in columns, giving a close resemblance to the zona fasciculata of the normal adrenal.

There were very few well-defined blood-vessels, but in some parts slight accumulation of red corpuscles.

For the accompanying illustrations I am indebted to my friend and colleague in the Pathological Department of the Owens College, Dr Moore, who has very carefully prepared them from my sections by means of the camera lucida.

The present example can, I think, without hesitation, be considered one of adenomatous growth. Mr Bland Sutton, who has kindly given me his opinion on the specimen, says there can be no doubt as to its being a so-called "adrenal goitre" (3).

As Virchow and others have pointed out, the supra-renal, like the thyroid, may undergo a general enlargement, due apparently to pure glandular proliferation.

Rolleston (4) describes two forms of adrenal adenomata. The *first* occurs as multiple small yellowish nodules situated on the cortex of the organ. The *second* are met with as large growths, usually single, but sometimes occurring in each adrenal.

"They do not involve the whole of the organ, but form distinctly localised tumours, which may attain a very considerable size. They arise, as a rule, in the cortex, either from one or more of its zones, and project usually from one side, though the whole thickness of the organ may be affected."

Virchow has described certain adrenal adenomata under the name of 'struma lipomatosa supra-renalis.'

Cases have also been recorded by Manasse (5), Pilliet (6), and others.

Bland Sutton (7) has described and figured a growth which he met with in a marmot, and considered to be an adrenal adenoma. In this instance there were also nodules in the liver.

It is interesting to note that tumours having the structure of adrenal tissue occasionally occur in connection with the peri-

adrenal fat, in the tissues near to the solar plexus, in the broad ligament, and in connection with the kidney (8-13).

These may be best considered as adenomata of accessory adrenals, and are conveniently spoken of as supra-renal "rests" (14).

REFERENCES, &c.

(1) *Manchester Royal Infirmary Post-Mortem Reports*, vol. 1893, p. 502, No. 146.

(2) The specimen has been added to the Pathological Museum of the Owens College.

(3) The term "adrenal goitre," although recently applied to these cases purely on the ground of analogy, is not an advisable one, and I quite agree with Dr Rolleston when he says:—"It must be regretted that a name of such purely local application as goître should be applied to a tumour in the abdomen."

(4) ROLLESTON, "The Goulstonian Lectures on the Supra-renal Bodies," *Brit. Med. Jour.*, 1895, i. p. 629.

(5) MANASSE (Paul), "Ueber die hyperplastischen Tumoren der Nebennieren," *Virchow's Archiv.*, cxxxiii, 1893, p. 391. Cases given, with illustrations.

(6) PELLLET (A.), "Troisième cas d'adenome de la capsule surrénale," *Bull. Soc. Anat. de Paris*, lxiv., 1889, p. 423.

(7) SUTTON (Bland), *Journal of Anat. and Phys.*, vol. xix. p. 458, pl. 23, fig 7; mentioned also in "Tumours—Innocent and Malignant," p. 99.

(8) GRAVITZ, *Virchow's Archiv.*, xciii. p. 39.

(9) HORN (Georg), "Beiträge zur Histogenese der aus aberrirten Nebennierenkeimen entstehenden Nierengeschwülste," *Virchow's Archiv.*, cxxvi., 1891, p. 191. Cases given, with illustrations and references.

(10) MAY (Richard), "Beiträge zur Pathologischen Anatomie der Nebennieren," *Virchow's Archiv.*, cxviii., 1887, p. 446.

(11) M'WEENEY (Edmond), "On Kidney Tumours derived from Supra-renal 'Rests,'" *Brit. Med. Jour.*, Feb. 8, 1896. Numerous references given.

(12) MORRIS (Henry), "Lectures on the Surgery of the Kidney," *Brit. Med. Jour.*, 1893, i. p. 2.

(13) THOMA (Richard), *Text-Book of General Pathology and Pathological Anatomy*, trans. by A. Bruce, 1896, vol. i. p. 566. Gives references.

(14) Many useful references will also be found in Dr Rolleston's valuable lectures, already referred to.

ON THE STRUCTURE OF THE RED GLANDS IN THE SWIM-BLADDER OF CERTAIN FISHES. WITH A NOTE ON THEIR POSSIBLE FUNCTION. By SWALE VINCENT, M.B. Lond., *Demonstrator of Physiology, and Assistant Lecturer on Histology, Mason College, Birmingham*, and A. STANLEY BARNES, B.Sc. Lond., *Assistant-Demonstrator of Physiology in Mason College.* (PLATE IX.)

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(From the Physiological Laboratory, Mason College, Birmingham.)

INTRODUCTORY.

THE literature of the swim-bladder is very extensive, but the papers which deal in a satisfactory manner with the minute structure of the “red bodies” or “blood-glands” in its interior are comparatively few. Moreover, the observers are not agreed among themselves as to several points, and some facts have been overlooked entirely. Very few of the drawings we have been able to find give anything like an adequate representation of the microscopic appearance of these structures. We shall not enter

into any discussion of the general functions of the swim-bladder, but simply confine our attention to the histology of the above bodies, with brief reference to their physiology.

Some observers have laid great stress on results obtained by injection of the blood-vessels. But the blood-vessels are not the only constituents of the "red bodies," nor indeed the most important; and these writers have failed to notice the exact arrangement of structures other than the blood-vessels.

Both in Corning's paper (3) and in that of Coggi (2) the drawings appear for the most part too diagrammatic.

The species examined by Corning and by Coggi were quite different in the two cases; and our specimens have been different still, the only exception being the eel which has been examined by Corning. But there is no reason to suppose that there are any fundamental differences between the different species in regard to the essential structure of the organ which concerns us.

1. HISTORICAL.

Here we can only mention some of the more important papers which deal specifically with the red glands.

The "red-bodies" in the swim-bladder of certain Teleosts have been known for a very long time. Thus Gautier Needham (16) seems to have first noticed their existence in 1668, and his discovery was followed by many observations by Redi (23), Ray and Willughby (22), Perrault (17), Petit (18), Koehltreuter (9), Monro (11), Fischer (7), and others. But the earliest exact description of their gross anatomy is that of Delaroche (5) in 1809. He found the "red-bodies" to be present, as did Perrault and Monro, in all those species which have no *ductus pneumaticus*, and also in the eels, although they have a duct. Delaroche gives a description of the naked-eye anatomy in the Gadidæ, Triglidæ, Percidæ, some of the Labridæ, and many others. In the same volume of the *Annales du Muséum* is a "Rapport" by Cuvier (4), in which is given a good history of the subject, and a discussion of the views of Delaroche about the "red-bodies." Neither Delaroche nor Cuvier made out their proper glandular elements; in fact, the former says definitely, "Les parois de la vessie ne contiennent, dans leur épaisseur, aucune glande; car il est évident que l'on ne peut pas regarder comme tels les corps rouges dont nous venons de donner la description."

Following this were several notices by Rathke (20 and 21), Berlak (1), and others, but J. Müller made the next step in advance (12, 13, 14, and 15). In 1840 (14) he gives a description of the "border" of these bodies as a gland connected with the *rete mirabile*, for the excretion of the air of the swim-bladder. He says there is no clear com-

munication between the cells of this border and the cavity of the bladder, but that there are occasional appearances of lumina in transverse section.

About this time, too, was written Jacobi's work (8), and a paper by Quekett (19), who describes and depicts the "red-bodies," laying great stress on their vascular arrangements, but apparently overlooking entirely the "cellular border," the proper glandular part.

The next communication to be noticed is that of Reinhardt (24) in 1852. In 1854 Stannius (26) gives a brief account of these "red-bodies." He says, "Sobald dieses Zerfallen der Arterien in diffuse Wundernetze aber bloss auf bestimmte Stellen der Schwimmblase sich beschränkt, eine Einrichtung, zu welcher die beim Hecht vorhandene den Uebergang bildet, constituiren sie die sogenannten 'rothen Körper.' Diese rothen Körper kommen am häufigsten und fast allgemein in geschlossenen Schwimmblasen vor, werden aber auch in solchen angetroffen, die einen Ductus pneumaticus besitzen, wie, z. B., bei den Muraenoiden"

"Bei manchen Fischen sind die Wundernetze von blassen oder gelblichen, mässig dicken, von der umgebenden Haut abgegrenzten zelligen Säumen umgeben, in welchen die baumartige Verzweigung der aus dem Wundernetze kommenden arteriellen Reiser Statt hat, während die übrige Fläche der Schwimmblase ihr Blut aus einfachen Blutgefässen erhält (Perca, Gadus)."

Mention is made of the structure of the red gland by Leydig (10), and by Schulze (25), and in 1886 by Wiedersheim (27).

But the two most important contributions are still more recent. In 1887 Coggi (2) states that he finds distinct gland lumina in certain places, and that the epithelium of the swim-bladder becomes modified as it passes over the surface of the body. It will be seen that in the main we agree with this observer.

In the following year, 1888, appeared Corning's paper (3), in which he divided the tufts of vessels going to the gland into arteries and veins, as the result of injection. Moreover, he denies the presence of lumina, and says that the glands are covered by flat epithelium continuous with that of the rest of the bladder. In criticising Coggi's work, which he had almost overlooked, he says that this observer considers that "sich das innerste Epithel der Schwimmblase nicht über die Blut drüsen hinziehe." What Coggi actually says is, "Il Müller ammetteva che una sottilissima continuazione della membrana interna della vescica natatoria coprisse questi orli o lembi. Se non che una sezione di qualunque corpo rosso di questo tipo mostra all' evidenza che l'orlo o lembo è precisamente l'epitelio interno della vescica, che ha subito modificazioni speciali."

2. METHODS.

The tissues have been mostly hardened in spirit, stained in bulk with Ehrlich's hæmatoxylin, embedded in paraffin, and cut with the rocking microtome. Some, however, have been stained

in borax-carmine and picro-carmine. Others, again, have been cut fresh with the freezing microtome, and the individual sections stained in various ways.

In the case of the eels the bladder was injected with a 50 p.c. solution of commercial "Formalin," cut out, and suspended in formalin for about three hours, by which time it was well hardened; sections were then cut, and stained in the usual way.

The species we have been able to examine are:—

Gadus morrhua, *Gadus aeglefinus*, *Merluccius vulgaris*, *Molva vulgaris*, *Zeus faber*, *Trigla pini*, *Anguilla anguilla*.

3. ANATOMY.

The "red-bodies" may be divided into two groups in the species we have examined. In the first group, A, e.g. in *Gadus morrhua*, the "red-bodies" may be properly called "glands" (see fig. 5). As the lining epithelium of the swim-bladder passes over the mass of capillaries it becomes modified to form a distinctly glandular epithelium in a manner to be fully described below. In the second group, B, represented by *Anguilla anguilla* (see figs. 4 and 8), the red-bodies consist solely of a mass of capillary blood-vessels covered by an unmodified continuation of the internal epithelium of the bladder. We shall describe the glands in the first group, and then give a short account of the bodies of the eel.

A.

Gadus morrhua.—When looked at with the naked eye (fig. 5) the single red gland of this fish is seen to lie on the dorsal surface of that portion of the swim-bladder which lies immediately behind the stomach. In one specimen the long axis of the gland was parallel to that of the body, and the size was 4 cm. \times 2.5 cm. In another the dimensions were 8½ cm. \times 5 cm. Its free surface showed many small clubbed processes, packed tightly together; each consisting of a red mass of tissue, surmounted by a cap of yellowish mucilaginous-looking material (fig. 5). The red gland is firmly fixed at the hilum; but, within limits, glides easily at its circumference over the wall of the swim-bladder; this hilum is in the middle line of the red gland, and placed near the anterior end of it.

Microscopically, the structure seems to be identical with that of *Gadus aeglefinus* (q.v. and cf. fig. 2).

Gadus aeglefinus.—The red gland is an oval mass of a blood-red colour, compounded of a large number (about 200?) of club-shaped masses of tissue, and covered by a coating of the same yellowish material described in *Gadus morrhua*. It is situated on the anterior part of the ventral wall of the bladder.

When examined with the microscope the gland is seen to be composed of the club-shaped masses above mentioned, packed tightly together; each mass being fixed at its thinner extremity, at which point the vessels enter and leave the nodule, and at which point also the epithelium of the swim-bladder becomes continuous with that covering the nodule.

This latter consists essentially of two parts:—(1) a mass of capillary blood-vessels, lying side by side, conveying blood to and taking blood from the second parts, (2) a glandular portion. When the capillaries arrive at a point about .2 mm. from the free surface of the gland (fig. 3), they interdigitate with involutions of the glandular epithelium, which dips down between them, and forms a covering for them, thus constituting tubular glands, .2 mm. in length. A lumen can in most cases be readily made out, of a width up to $11\ \mu$ (fig. 2, *l.*).

The cells of this epithelium average $28\ \mu \times 13\ \mu$ in size; their protoplasm has a faintly granular aspect, and is striated (fig. 2, *gld.e.*). The nuclei are large, and have a tendency to be oval.

Separating the glandular epithelium from the blood-vessels are frequently seen perivascular lymphatic spaces (fig. 2, *p.vs.*), with occasional leucocytes (fig. 2, *wh.c.*).

Merluccius vulgaris.—The macroscopic appearances of the red gland do not differ materially from those of *Gadus morrhua* (q.v.). One point of difference is that in *Merluccius vulgaris* the body is much more transparent and gelatinous. Its greatest length is about 6 cm., greatest breadth 3 cm., in a fish of 60 cm. length.

As to minute anatomy, when the gland is examined with a low power of the microscope, it appears to consist of deeply-stained masses of capillaries, separated into bundles, about .5 mm. in diameter, by septa of fibrous tissue. In a transverse

section, seventy or eighty of these capillary masses will be seen cut in various directions. Those near the free edge of the gland are observed to have the same relations to the glandular epithelium as already described for other species. In some of these capillary masses upwards of a thousand vessels can be counted.

Molva vulgaris.—Macroscopically, the red gland of this fish does not differ from that of others of the cod family.

The preparation of this red gland for microscopical examination was very successful, showing very clearly the relations of the blood-vessels to the gland (see fig. 1). The structure is very similar to that of *Gadus aeglefinus*, already described. The tubular gland arrangement is particularly well seen, and in many places portions of its secretion may be seen either in the lumina (*l.*), or on the edge of the gland (*m.*).

Zeus faber.—In this species the red glands occupy about the anterior half of the internal surface of the ventral wall of the swim-bladder. The epithelium is loose everywhere, except at the hilum of the glands. These consist of worm-like, blood-red elevations, of an average width of 4 mm. (fig. 6). They are arranged in the form of two figures "3," right and left, face to face, one slightly posterior to the other. The continuity is completely broken at certain places. The arrangement of blood-vessels is also shown in fig. 6.

In microscopic preparations (stained with Ehrlich's hæmatoxylin, Kleinenberg's hæmatoxylin, borax-carmin, and picrocarmin) of the glands of the John Dory, we have had no difficulty in tracing the continuity of the internal epithelium lining the general cavity of the swim-bladder with the proper glandular structure of the organs.

The arrangement appears to differ slightly in different parts of the gland. In some sections a strand of fibrous tissue is given off at an acute angle from the main wall of the swim-bladder, separating the rete mirabile from the red gland proper. A similar appearance is represented by Coggi in *Serranus scriba*. In other sections there is no such partial fibrous partition, but at one side of the organ the epithelium is prolonged into a deep fissure, at the deepest part of which the transition takes place. We have not been able to obtain sections which show the direct

transition to the tubular glands, but there is no doubt that the epithelium takes on fairly suddenly a markedly glandular aspect. In both cases the nuclei of the cells of the internal epithelium lining the general cavity of the swim-bladder, as this approaches the glandular region, can be seen to form several layers, and is quickly transformed into glandular structure.

The arrangement of the elements is practically the same as in the species described above. The gland cells are about $15\ \mu \times 10\ \mu$ with nuclei about $6\ \mu \times 4\ \mu$.

Trigla pini.—In the specimen we examined there were three glands on the ventral surface of the swim-bladder (fig. 7). The chief one is of an irregular heart-shape; the other two are smaller and still more irregular. The glands are flatter than in the other species we have examined, otherwise their general appearance is the same.

The microscopic appearances are somewhat different from any of the other species we have examined. The tubular-gland arrangement is not well shown, nor can the intimate relations of the blood-vessels to the gland be made out with certainty.

B.

Anguilla anguilla.—In this fish, as previously intimated, there is no true red gland, but only what we may call "red-bodies," or "vascular bodies." Of these there are several. The two chief ones are placed, as seen in fig. 8, guarding the entrance to the pneumatic duct. The drawing represents the appearances seen on the ventral wall of the swim-bladder, when viewed from the interior. The arrow indicates the direction in which the section is taken, depicted in the plate (fig. 4).

Microscopically, the "red-bodies" of the eel are seen to consist only of masses of capillaries, tightly packed together, and covered by the unmodified internal epithelium of the swim-bladder.

Fig. 4 shows many of the smaller capillary masses (up to about $\frac{1}{2}$ mm. diam.) in the wall of the *ductus pneumaticus*.

Thus the intimate structure shows that these "red-bodies" of the eel are only partially comparable to the red glands of the Gadidæ.

From the foregoing descriptions it appears that in fishes which do not possess a *ductus pneumaticus*, the structures with which we are concerned consist of two parts, vascular and glandular. In some fishes, *e.g.* the Gadidæ, these two parts seem to be more or less broken up into many small nodules—each still containing both vascular and glandular elements: in others, *e.g.* in *Zeus faber*, the red body is not thus subdivided, but forms a long worm-like body, only interrupted at rare intervals.

In all these cases, however, the essential microscopic structure is similar. The internal epithelium of the swim-bladder is in all cases modified into a glandular layer as it passes over the vascular part of the organ.

This epithelium, in passing over the gland, is thrown into rugæ, the deeper parts of which penetrate into the vascular mass, or rather interdigitate with numbers of capillaries coming from and going to the vascular part of the body (fig. 3). In this way we have formed on the free surface of the organ a number of glands much resembling those of the cardiac end of a mammalian stomach in appearance, and receiving a very free supply of blood (see diagram, fig. 3).

Each gland is a simple tubular structure: the cells of which it is composed form a single layer resting on a basement membrane, and showing in most cases a very definite lumen.¹

The cells of these glands are short columnar, and often faintly granular; in many cases they are seen to be distinctly striated (fig. 2), the direction of the striæ being towards the lumen of the gland. The nuclei are large. These glands seem to secrete a mucilaginous material, which has a granular appearance when stained with hæmatoxylin (*m.*, fig. 1).

The basement membrane on which these cells rest lies bounding a perivascular lymphatic space (*p.v.s.*, figs. 2 and 3), and during life must be bathed with lymph derived from the thin-walled capillaries which lie almost in contact with it. The capillaries are derived from the vascular portion of the red body (see fig. 2 and the diagrammatic representation in fig. 3).

¹ The question of a lumen to these glands has long been a disputed point. Corning failed to find them in the species he examined; Coggi terms them spaces left by the foldings of the epithelium. We agree with Coggi as to the existence of these spaces, but prefer to call them the lumina of the glands.

If we trace any particular capillary, we find it formed at a considerable distance from the border of the gland by the breaking up of a large artery; then, in company with many hundreds of such capillaries, it makes its way towards the surface; arrived at its most superficial part, in the small column of tissue which intervenes between the adjacent tubular glands (see fig. 3), it doubles back upon its former course, and on arrival at a point similar to the one at which the artery breaks up, several of these return-capillaries unite, forming the companion vein to the artery.

In this way each tubular gland lies in a regular nest formed by several of these capillary loops, so that a section of the whole structure shows masses of capillaries budded off from a central mass of capillaries interdigitating with involutions of the glandular epithelium.

Fig. 3 is a rough diagrammatic representation intended to show this arrangement.

Corning has discriminated between arteries and veins in what we have usually spoken of as the "capillary masses." This he has done by means of a series of injections. He says—

"Ich machte die Injektionen der Arterien von der Radix Aortæ aus; die der Venen vom Sinus venosus aus; die Präparate stellten sich kaum verschieden dar, mit dem Unterschied jedoch, dass bei Injektion von der Aorta aus die arterien, bei derjenigen vom Sinus venosus aus die Venen praller gefüllt und folglich dunkler gefärbet erschienen. Es war daher leicht, Venen und Arterien zu unterscheiden."

This method would certainly give some idea of the distinction between the smallest arterioles and smallest venules, but we are doubtful whether it would be more than a very rough method of distinction, that it would be, in any given case, an infallible test as to whether a particular small vessel were to be called artery or vein. Much would depend, it appears to us, on the strength of the injecting force. However this may be, we have failed to make out anything in the minute structure which would warrant us in dividing up the "capillary masses" into arterioles and venules.

Another point in Corning's paper which requires notice is in reference to the internal epithelium of the swim-bladder. We

have already shown pretty clearly that his views on the arrangement of this structure are at variance with the facts, at least in all the species we have examined, but a word remains to be said on his method:—

“Die Anfüllung der Schwimmblasen mit chromessigsäure war zur Erhaltung des inneren Epithelbelags unbedingt nothwendig.” Again, at the end of his paper, in a note referring to Coggi’s work, he says, “Doch giebt Coggi nicht an, ob er die Schwimmblasen der von ihm untersuchten Fische mit Alkohol gefüllt habe, was ich zur Erhaltung des inneren Epithelbelags für durchaus nothwendig erachte.”

It is by no means clear why this particular process should be absolutely necessary in order to retain the epithelium in its proper condition. It is, of course, a very usual and a very good plan for hollow organs in general. In many of our preparations this was, however, not done, and yet the internal epithelium, and that modification of it we have described as constituting the glands, was beautifully shown.

Moreover, it is more than probable that this method of distending the bladder by the injecting into it of fluids would seriously modify the form of the epithelium. Chrom-acetic acid is said to be admirably calculated not to cause shrinkage, but when present under pressure some change in the shape of the epithelium cells might easily occur. Again, is it not possible that this fluid thus injected might have precipitated the mucoid substance secreted by the tubular glands? The appearance of this, when stained, might possibly have been interpreted by Corning as a flat epithelium. Since this secretion may also be seen blocking up the lumina of the glands, it is very probable that this may have caused them to be overlooked by the above observer.

In *Fierasfer* Emery (6) has described two distinct structures, one with the modified epithelium, and one without it.

4. NOTE ON THE FUNCTIONS OF THE RED GLANDS.

The fact that the red glands are only found in those bladders which are devoid of a *ductus pneumaticus* can only be regarded as significant of some function in regard to variations in the amount and composition of the gases in the bladder from time to time.

As to how it functionates in this respect nothing definite

is known. But we cannot believe, from a careful study of its microscopical structure, that it is simply concerned with the elimination or absorption of gases. The minute anatomy, as we have already pointed out, is such as we are accustomed to associate with a liquid or semi-solid secretion. If its function had sole relation to gases, we should expect as thin an epithelium as possible to separate the blood in the capillaries from the cavity of the bladder; a structure, in fact, resembling that of the pulmonary alveoli.

In all the species we have examined we have observed what appeared to be a moist film of secretion covering the gland; and in a particularly large and quite fresh cod, this amounted to a copious secretion filling up the irregularities of the surface, and, further, forming a pool at one extremity of the organ. This material was carefully collected and examined chemically. It was viscid and slimy, and of an opaque milk-white aspect. Under the microscope no cellular elements were seen, but only indefinite granules and globules.

This was diluted with 1 per cent. sodium bicarbonate, thoroughly mixed, slightly acidified with dilute acetic acid, and allowed to stand for twenty-four hours, when a white precipitate was deposited, which might be mucin, a nucleo-proteid, or possibly alkali-albumin.

A small portion of this was boiled with dilute hydrochloric acid for two minutes, then tested for a reducing sugar; this gave a negative result. From this we conclude that the material did not contain mucin.

To test for a nucleo-proteid, a second portion of the above precipitate was digested with gastric extract (Parke, Davis, & Co.'s aseptic pepsin) for several hours, when an insoluble residue, presumably nuclein, remained. This was burnt, oxidised with strong nitric acid, evaporated nearly to dryness, taken up with a little water, and warmed with ammonium molybdate. A fairly copious bright yellow precipitate indicated the presence of a considerable amount of phosphates, so that the formerly obtained insoluble residue was almost undoubtedly nuclein; thus we may conclude that the chief ingredient of the secretion is a nucleo-proteid.

We do not wish to lay too much stress on the results of a single

experiment, and would not affirm with absolute certainty that there is no mucin in the secretion, but it is perhaps worth noting in this relation that no goblet-cells were to be discovered in any of our sections. Moreover, the tissue does not stain after the manner of a mucous gland, as it takes the stain more deeply than these do.

As to whether this secretion is simply a lubricant, having only physical effects, or whether it may play some important part in the secretion or absorption of the gases, we must leave an open question. The enormous blood-supply of the red-glands lends some support to the latter suggestion. We hope, when opportunity offers, to make some further investigations on the nature of this secretion.

5. SUMMARY AND CONCLUSIONS.

1. The "blood-vascular organs" are divided into two groups. (1) In fishes with no *ductus pneumaticus*; in this case they are *true glands*. (2) In fishes which possess a pneumatic duct, as the eels; in this case they are simply masses of capillaries, and we may retain the name "*red-bodies*."¹ In this second group the "red-bodies" are covered by an unmodified continuation of the flat epithelium of the bladder.²

2. *The red glands consist of very definite gland-tubules.*

3. *These tubular glands have distinct lumina.*

4. *They secrete a slimy substance which contains a nucleo-proteid, and so far as we can make out, no mucin.*

5. *The internal epithelium of the swim-bladder does not pass unaltered over the red glands, but becomes modified to form the gland-tubules.*

¹ In fishes with a pneumatic duct there is, of course, as a rule, no such "red-body" at all; but the eel is a type of a fish with a pneumatic duct and a vascular "red-body."

² Thus the apparent anomaly of a physoclistous fish possessing structures supposed to be characteristic of the physostomi is explained by the distinction we have made above. Mere anatomical investigation is here very misleading.

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7. EXPLANATION OF PLATE IX.

Reference Letters common to Figures 1-4: *art.*—large artery; *bld. c.*—blood-corpuscle; *cap.*—capillary; *e.*—epithelium of ductus pneumaticus; *f.*—fibrous tissue; *gld. e.*—glandular epithelium; *l.*—lumen of tubular glands; *m.*—mucinoid secretion of tubular glands; *p.*—pigment layer of swim-bladder wall; *p.r.s.*—perivascular lymphatic space; *wh. c.*—leucocyte.

FIG. 1.—Vertical section through a nodule of the red gland of *Molva vulgaris*, seen under a magnifying power of 60 diam. Drawn with camera lucida.

This drawing is not in the least diagrammatic, and shows very clearly the manner in which the capillaries from the capillary-mass at the base of the gland interdigitate with the infoldings of the glandular epithelium, which may thus be said to form tubular glands. The nodule is seen to be supported at the sides by a considerable amount of fibrous tissue.

FIG. 2.—Vertical section of a portion of red gland of *Gadus aeglefinus*. Magnified 400 diam.

This section gives an idea of the glandular look of the epithelial cells, showing their transverse markings and granular aspect; the structure is very similar to that depicted in fig. 1.

FIG. 3.—Diagram of arrangement of vessels with regard to the tubular glands in fishes with no *ductus pneumaticus*. This corresponds with the description given on page 552.

FIG. 4.—Transverse section of part of the *ductus pneumaticus* of *Anguilla anguilla*. Drawn with camera lucida; magnifying power 50 diam.

This drawing shows the fibrous and pigment layers of the swim-bladder, inclosing masses of capillaries over which passes the unmodified epithelium lining the duct.

FIG. 5.—Red gland of *Gadus morrhua*: *a.*—posterior part of red gland; *b.*—its yellow margin; *c.*—swim-bladder; *d.*—vessel.

FIG. 6.—Red glands of *Zeus faber*: 1. wall of swim-bladder; 2. red gland, with 3. its yellowish border; 4. point of origin of vessels, 5.

FIG. 7.—Red gland of *Trigla pini*: 1. ant. end of red gland; 2. yellowish margin of red gland; 3. wall of swim-bladder; 4. accessory glands.

FIG. 8.—Red bodies of *Anguilla anguilla*: 1. chief "red-bodies"; 2. two blood-vessels; 3. opening of *ductus pneumaticus*; 4. *ductus pneumaticus*, faintly seen.

**LARGE CYSTIC MYXOMA ATTACHED TO THE COLON
OF THE SHEEP.** By GORDON SHARP, M.B. Edin., *late
Research Student in Pharmacology in the Owens College,
Victoria University.*

THIS tumour, although intimately attached to the colon of a healthy sheep, in no way narrowed the lumen. In order to get the clearest idea of the relationship of bowel and tumour to each other, all except about nine inches of the alimentary tract was cut away, one of the cut ends was tied, the bowel inflated, and the other end tied. The position of the tumour and its general appearance could then be well seen. The animal was healthy, and the tumour as it lay in the belly was covered with masses of fat. When removed from the body it was stripped of the surrounding fat, and it was then found to be a round, white, opaque swelling, evidently containing a semi-fluid body. The circumference, devoid of the encircling fat, was twelve inches.

When cut into, the sac was found to have a thickness of one-eighth of an inch, and was tough in texture. The contents of the tumour were (1) a thin, film-like, whitish membrane, dividing the cavity into spaces; (2) a tenacious, fluid-like body, opaque in appearance. The film-like membrane was, after staining with picrocarmine solution and mounting in Farrant's solution, examined by the microscope, and was seen to be made up of branching filaments and small round cells. The contents of the tumour contained sodium chloride, became more tenacious on boiling, and when exposed to the air set into a firm jelly. Examined by the microscope, cells and their remains and filaments were found, but nothing else of importance. A section of the wall of the tumour was cut and examined, and had a structure as follows: In some parts the tissue is made up of a compact fibrous mass, while in other parts branching filaments are seen, showing a loose texture, with spaces containing a structureless material. This second condition is most likely the more primitive, and points to the life history of the sac. Starting with a small

myxomatous mass attached to the bowel, and originating from the remains of a primitive tissue, we find the tumour getting larger and larger within its walls. The walls, instead of giving way as so often happens in myxomatous growths, become thickened and stretch out, accommodating themselves to the increasing quantity of contents.

As already mentioned, the tumour was divided into spaces by a thin membrane containing small round cells. This is important, for it points to the very close relationship existing between myxoma and sarcoma. Had the collection of round cells gone on increasing in great numbers, so as to be relatively the larger element present, we should have had a sarcoma in place of a myxoma. Thus the dividing line between a simple and a malignant growth is not as wide as we are sometimes led to believe. The factor which decides would appear to be often the stimulating agent which is at work.

Myxomatous growths of small size are not uncommon in sheep, but of the large size of the present case very rare. They originate from the embryonic tissue of the peritoneum and intestinal walls. Another rare feature in this tumour is the thickness of the walls, for as a rule the walls are very thin. The comparative pathology of new growths in the abdomen is interesting. Starting with the sheep, we have a fairly highly specialised animal in which myxomatous tumours are common. If we allow that the horse occupies a higher place, we have a different set of tumours of common occurrence, namely, the sarcomatous; melanotic sarcoma being largely found in that animal.

Lastly, coming to man, the most highly specialised of all animals, we have, as the commonest abdominal new growths, the cancers, and differing much from both myxoma and sarcoma. The cancers are intimately associated with the bowel, and may kill by occluding the cavity, really starving the unhappy possessor. Their tendency is to kill their victims. Sarcomata, on the other hand, are not so closely connected with the bowel, being growths from the intestinal appendages, and although malignant, are not so fatal in their effects as the common growths found in the human subject. Lastly, the myxomata have no intimate connection with the bowel proper, being growths from the neighbouring embryonic tissue, and in their effects they are

benign, causing inconvenience by their size rather than by constitutional disturbance. As one goes up the scale, malignancy increases.

Primary myxoma is rare in man, but on the umbilical cord at birth one sees very similar growths to those found in the sheep—in fact, the resemblance is as close as can well be. In the nose, too, we find the mucous polyp in young adults and at other ages. And this polyp sometimes develops into true sarcoma, showing how close the relationship between the two.

Secondary myxoma is common in the human being. Here it is a degenerative process—a reversion to an ancestral tissue. It is Nature's effort to free herself of an unwelcome guest—an effort to change a malignant into a non-malignant growth; or in the case of a large simple tumour, such as a fatty growth, an effort is made to change it into an absorbable substance, namely, mucus. In considering the very wide and very difficult question of the treatment of malignant new growths, we have herein a hint which should not be let pass unheeded.

**A COMPARISON OF THE ANOMALOUS PARTS OF
TWO SUBJECTS, THE ONE WITH A CERVICAL
RIB, THE OTHER WITH A RUDIMENTARY FIRST
RIB. By LEWIS E. HERTSLET, Student of Medicine.
WITH NOTES ON THE CASES, by ARTHUR KEITH, M.D.,
*Demonstrator of Anatomy, London Hospital Medical College.***

THE first case (Case A) is that of an ordinary seventh cervical rib, the subject being a small and ill-developed woman, aged about 60; the rib appears on both sides, that on the right being a little the longer.

There is nothing extraordinary about this case, but it is interesting from its similarity to the second.

Case B, which presents the rare abnormality of a rudimentary first dorsal rib, is of rather more than ordinary interest.

The rib on both sides, which articulates with the body and transverse processes of the 8th vertebra, does not extend as far as the sternum in front, but has a pointed extremity about 5 or 6 c.c. from the upper angle of the sternum.

This subject was a male about 35 or 40 years of age, and from his appearance was probably of Magyar origin. He died from tuberculosis of the lumbar vertebræ.

On comparing these two cases in the following tabular form, it at once becomes evident that there is very little difference in the arrangement of the abnormal parts of the two subjects, except, of course, that in Case A the rudimentary rib is placed one vertebra higher up.

Case B possesses three other rather important abnormalities: they are:—

(1) A sterno-scapular muscle, which represents the subclavius, being inserted into the upper border of the scapula, over the supra-scapular notch, the outer end of the clavicle, and the trapezoid ligament; it appeared on both sides.

(2) The styloid ligament on the right side is ossified, and from it a small muscle, probably a segmentation of stylo-

pharyngeus, takes origin, and is inserted into the great horns of the hyoid bone, and also into the deep cervical fascia.

(3) The levator anguli scapulæ arises with the scalenus medius from the transverse processes of the 1st, 2nd, 3rd, and 4th cervical vertebrae, but the slip taking origin from the 3rd is

(Right side of Case B.)

(Left side of Case A.)

abnormal, and is inserted into the upper border of the 2nd rib, at its angle, on a level with the insertion of the serratus posticus superior.

NOTES.

Either the 6th, 7th, or 8th segments of the body may carry rudimentary ribs; the 6th very rarely, the 7th (of which Case A is an example) frequently; the 8th (which Case B exemplifies)

NAMES OF PARTS.	CASE A.		CASE B.
	Left Side.		
<i>First Rib.</i> Articulates with	Bodies of VI. and VII. vertebral disc.	Bodies of VII. and VIII. vertebral disc.	
Anterior end.	Fairly large tuberculated process.	Smaller do.	
Dimensions.	Neck, 4 cm.	3.5 cm.	4 cm.
	Shaft, 3 cm.	4 cm.	5 cm.
	Head to tip, 6 cm.	4.5 cm.	5 cm.
	Tip to sternum, 8 cm.	7 cm.	8.5 cm.
Cartilage.	Small piece attached to sternum by ligaments.	Do., forming part of sternum.	Do.
	Calcified.	No ligaments.	Not calcified.
<i>Second Rib.</i>	Resembles a 2nd (true) rib.	Do.	Resembles a 1st rib.
Cartilage.	Joined to whole of side of manubrium.	Joined to junction of manubrium and meso-sternum.	Joined to junction of manubrium and meso-sternum.
<i>Eighth Rib.</i> Total No. of ribs,	Ends 4 cm. from sternum. 12	Reaches sternum. 12	Ends 4 cm. from sternum. 12
<i>Scalenus Anticus.</i> Origin.	Anterior transverse processes of V. and VI. Vertebrae.	Do.	Do.
Insertion.	1st true rib and Thoracic membrane.	Becomes continuous with muscular band between neck of cervical rib and sternum.	Part becomes continuous with Scalenus medius, and part is inserted into Thoracic membrane.
Relation to Subclavian Artery.	Passes over artery.	Do.	Chiefly under, slight slip over.
Height of Pleura,	Disc between VII. and VIII.	Do., a trifle higher.	Level of middle of body of VIIIth
Subclavian Artery.	Passes above fibrous tissue prolonged from the rudimentary rib.		Passes above fibrous tissue prolonged

Vertebrae. Transverse Processes.	Anterior.		Posterior.		Do.
	Large. None. None.	Small. Fairly large. Very large.			
V C. VI C. VII C.					Do.
Spinous Processes.					
V C. VI C. VII C.					
Articular Processes.					Do.
Number.					
Vertebral Artery pierces transverse process of			5th Vertebra.		5th Vertebra.
Deep Cervical Artery goes	7th and 8th Vertebra.				Do.
m and remnants of 1st cartilage.					
; this branch gives off Phrenic. ith branch of IVth. a separate trunk. branch to VIIIth. branches of VIIth and IXth. costal space and gives branch to VIIIth. costal space and gives branch to IXth.					

so rarely that this was the fifth case that had been recorded in Britain.

Helm, who had dealt exhaustively with this anomaly, and given full references to its literature (*Anat. Anz.*, 1895, B. x., p. 540–554), had been able to collect only sixteen recorded cases in the anatomical literature of the last twenty-five years.

It is remarkable that Zuckerkandl had found this anomaly four times in sixty Austrian subjects; Struthers had observed another specimen in an anatomical collection in Vienna, and before discovering a rudimentary first rib in Case B, the subject had been set down as a Magyar. It will probably be found that the frequency of this variation is a characteristic of the Magyars.

The opinions held as to the nature of rudimentary cervical and thoracic ribs are of some interest.

Wiedersheim, in his *Bau des Menschen* (of which there is an English translation, edited by Professor Howes), regards the occurrence of cervical ribs as an atavism, of rudimentary first dorsal ribs as a progressive variation, so that in Case A we see what we have been, and in Case B we see what we shall be.

It has still to be shown, however, that the first rib, in its most fully developed form, is not the fittest arrangement of parts for the human race.

Arbuthnot Lane (*Journ. of Anat. and Phys.*, 1886, vol. xx. p. 392) regards rudimentary first dorsal as cervical ribs, holding that there is in such cases an extra vertebra intercalated in the cervical series; so that, according to this author, Cases A and B are exactly similar, except that there is an extra and abnormal vertebra present in Case B.

An extra vertebra may come to be present by the subdivision of a normal segment, for partial segmentation of vertebræ and ribs into two is occasionally found; but the arrangement of nerves, arteries, muscles, and bones found in the cases recorded above, countenances neither this nor Arbuthnot Lane's theory.

In the language of Bateson (*Materials for Variation*), Cases A and B may be said to exemplify forward and backward *meristic* variations of a homœotic nature; that is to say, in Case A there is a transference forwards of some of the characters of the 8th segment to the 7th, while in Case B there is a transference

backwards of some of the characters of the 8th to the 9th segment.

Looking at these two specimens, there can be no doubt whatever that the costal characters of the 7th segment of Case A have been almost exactly reproduced in the 8th segment of Case B.

Perhaps the most useful manner of viewing variations of the cervical and dorsal ribs is to regard them as examples of what Galton would call deviations from the law of averages; that is to say, a fully developed rib on the 8th segment is the bull's-eye of the developmental energy, but its target extends from the 6th to the 9th segment.

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ANOTHER HEART WITH MODERATOR BAND IN THE
LEFT VENTRICLE. By Professor Sir WILLIAM TURNER,
F.R.S.

IN February 1893 I exhibited and described to the Anatomical Society¹ a human heart, in the left ventricle of which three slender bands passed from the septal wall across the cavity to the posterior wall of the ventricle. From their attachments they would doubtless have exercised during life a moderating influence over distension of the left ventricle.

I have now before me another human heart, in the left ventricle of which a slender moderator band, 38 mm. long, arose by a conical muscular base, 9 mm. in greatest diameter, from the anterior or septal wall. It passed directly across the cavity, to be attached to the posterior wall by a conical muscular base, 10 mm. in greatest diameter. This attachment was in immediate relation with the origin of the large papillary muscle, which arose close to the left border of the ventricular wall. The septal base of the band was smooth and not subdivided, but the posterior base was broken up into slender columnæ carneæ. The band itself was about half a millimetre wide at its slenderest part, and consisted there of a fine fasciculus of muscular fibre, invested by endocardium.

The posterior wall of the ventricle was broken up in the usual manner into columnæ carneæ, and gave origin at its margins to two large papillary muscles. The anterior septal wall, on the other hand, presented an extensive smooth unbroken surface, extending upwards into the aortic vestibule; but for from 3 to 4 centimetres above the apex slender columnæ carneæ were present in it. The septal origin of the moderator band was from near the lower part of the smooth area. The attachments of this band to opposite walls of the ventricular chamber would without doubt enable it to exercise a moderating influence on the dilatation of the cavity.

¹See Proceedings of the Society of that date, and *Journal of Anatomy and Physiology*, vol. xxvii., February 1893, p. xix.

I think it not unlikely that a similar moderator band may occur in the left ventricle more frequently than we at present suppose to be the case. The mode of opening the left ventricle commonly followed, viz., to transfix it at the base with the knife, and cut downwards to the apex, would necessarily divide the band and interfere with its recognition. In both the hearts in which I have seen this band the walls were not transfixed with the knife, but were carefully cut through near the anterior and posterior inter-ventricular grooves.

A distinct fleshy moderator band, possessing the usual attachments, was present in the right ventricle. In this specimen, as in the heart described in 1893, a considerable area, extending beyond the infundibulum properly so called, was smooth, and without columnæ carneæ.

ABNORMALITIES OF MUSCLES, NERVES, HEART,
VESSELS, AND LIGAMENTS, RECENTLY OBSERVED
IN THE PRACTICAL ANATOMY ROOMS OF THE
UNIVERSITY OF EDINBURGH. By DAVID HEPBURN,
M.D., C.M., F.R.S. Edin., *Lecturer on Regional Anatomy.*

THE following observations are selected from my note-book, not because the abnormalities described are in every instance entirely novel, but because they are of sufficient interest or variety to entitle them to re-description, even where their occurrence has already been recorded.

I.—ABNORMALITIES OF MUSCLES.

1. *Muscular slip from the Latissimus dorsi muscle to the Coracoid process of the Scapula.*

This slip of muscle, which was fan-shaped in appearance, arose by fleshy fibres from the anterior surface of the latissimus dorsi, near to its tendon of insertion. Passing upwards and outwards, it terminated in a fine tendon which was inserted into the tip of the coracoid process, between the origin of the coraco-brachialis and the insertion of the pectoralis minor. From the outer side of the tendon a flat fibrous prolongation was given off. This process was supposed to have joined the deep fascia of the upper arm, but it had been cut before its exact ending could be determined. A nerve of considerable size, and derived from the internal anterior thoracic, supplied the muscle in question.

This muscular slip presents one of the rarer forms of *axillary arch*, and is no doubt a variety of the *costo-coracoideus* muscle, although by some observers all axillary arches are regarded as remnants of the *panniculus carnosus*.

2. *Insertion of the Third Lumbrical Muscle in association with the Middle Digit.*

In this case the origin of the muscle was, as is usual, from the contiguous sides of the second and third tendons of the

flexor profundus digitorum, but very feebly from the latter tendon. It was inserted into the ulnar border of the common extensor tendon on the dorsum of the first phalanx of the medius digit. Thus the second and third lumbrical muscles were inserted into opposite borders of the same extensor tendon. The median nerve supplied the first and second lumbricals, while the third and fourth lumbricals were innervated from the profunda branch of the ulnar nerve. Macalister¹ and Wood have recorded instances of this variety.

2a. Abnormal Origin for the First Lumbrical Muscle.

This muscle possessed two heads of origin, of which one was normal, being attached to the radial side of the index tendon of the flexor profundus digitorum. The abnormal head arose in the fore-arm by a slender tendon attached to the deep surface of the flexor sublimis digitorum. This tendon passed downwards from the fore-arm along with the ordinary structures which travel behind the anterior annular ligament of the carpus. Subjacent to this ligament the tendon developed a muscular belly, which extended two inches in length, and had the proportions of an ordinary lumbrical muscle. In the palm this slip joined the normal head of the first lumbrical, which, as regards its insertion and its nerve supply, conformed to normal conditions. A modification of this variation stands first in the list which Professor Macalister gives in his Catalogue.

3. Unusual insertion of the Semi-membranosus.

This irregularity was found in one limb of a female subject whose muscular system was extremely well developed. At first the dissectors imagined that the semi-membranosus muscle was absent, but this was not the case. The tendon of origin was very thin, and fascial rather than membranous, but it occupied a fine line of attachment on its normal facet on the ischial tuberosity, and presented a normal relationship to the combined tendon of origin of the biceps and semi-tendinosus muscles. From this thin origin a tendon, more slender than a plantaris

¹ Macalister, *Catalogue of Muscular Anomalies.*

tendon, passed downwards and inwards, quite devoid of muscular fibres, for a distance of six inches. Then muscular substance commenced abruptly forming a flat strap half-an-inch in width, and fully four inches in length. This muscular belly ended in a flat membranous tendon, which ran forwards superficial to the rounded tendon of the adductor magnus, in front of which it fused with the deep fascia of the thigh subjacent to the adductor gracilis and sartorius muscles. No other insertion was present. There was no groove on the inner tuberosity of the tibia. The posterior ligament of the knee-joint was complete, but remarkably thin. The rounded tendon of the adductor magnus was distinctly prolonged beyond its femoral insertion, and was in direct continuity with the internal lateral ligament of the knee-joint. Consequently, the upper end of the internal lateral ligament was attached to the internal condyle of the femur, in close proximity to the adductor tubercle; while inferiorly the ligament was more than usually expanded, and was attached to the inner and hinder aspect of the head of the tibia as well as to the inner and upper aspect of the tibial shaft. None of the adjoining muscles appeared above average size. The rare nature of this variation is evident, since it differs from those recorded in Professor Macalister's Catalogue, and is not referred to in Quain's *Anatomy*. In one of the cases referred to by Professor Macalister, the muscle was reduced to a tendon whose inferior attachment was into the internal condyle of the femur. Sir William Turner¹ has also recorded a similar rudimentary condition of this muscle. These two cases most nearly resemble the one I have recorded, but they differ from it both as regards insertion and the absence of muscular fibres.

4. *Additional origin for the Iliacus Muscle.*

A strong tendinous slip, as large as the combined heads of origin of the rectus femoris muscle, arose from the dorsum ilii, immediately below and external to the anterior inferior iliac spine, and from the capsule of the hip-joint internal to the reflected tendon of the rectus femoris. The muscular fibres from this origin passed behind the rectus femoris, and blended at once with the iliacus

¹ *Jour. of Anat. and Phys.*, vol. xviii. p. 463.

muscle as it emerged from behind Poupart's ligament. Thus augmented, the iliacus muscle proceeded to its usual insertion.

This variation differs considerably from that which is recorded by Quain¹ under the term *Iliacus minor* or *Ilio-capsularis*, and which "arises from the anterior inferior spine of the ilium, and is inserted into the lower part of the anterior inter-trochanteric line of the femur, or into the ilio-femoral ligament."

On the other hand, it presents some points of resemblance to an origin which I have described in connection with the iliacus muscle of the Gibbon² (*Hylobates*), in which part of the muscle arose from the outer side of the tendon of origin of the rectus femoris.

Kohlbrügge³ has noted a similar origin in his work on the genus *Hylobates*. At the same time it should be mentioned that the rectus femoris muscle of the Gibbon does not possess a *reflected* tendon of origin, whereas both heads of the rectus femoris were present in association with the abnormality under consideration.

5. In the right foot of a subject from which the *peroneus tertius* muscle was entirely wanting, the *peroneus brevis* presented the following modifications of its tendon of insertion. The tendon divided into three portions, which were attached as follows:—

- (α) A small slip was inserted into the projecting tubercle on the base of the 5th metatarsal bone.
- (β) A slip, much smaller than the preceding, was prolonged on the dorsal aspect of the 5th metatarsal bone, to join the common extensor tendon on the dorsum of the 5th toe;
- (γ) The great bulk of the tendon was inserted into the *dorsal* aspect of the tubercle of the 5th metatarsal bone.

Coincident with these variations, the *abductor minimi digiti* of the same foot presented an important insertion into the

¹ Quain's *Anatomy*, vol. ii. pt. 2, 10th ed., p. 245.

² Hepburn, "The Comparative Anatomy of the Muscles and Nerves of the Superior and Inferior Extremities of the Anthropoid Apes," *Jour. of Anat. and Phys.*, vol. xxvi.

³ Kohlbrügge, *Anat. des Genus Hylobates*, 1890 (Dr Max Weber, Amsterdam).

proximal end of the tubercle at the base of the 5th metatarsal bone, in conjunction with the slip "a" of the peroneus brevis.

With regard to the peroneus brevis, the main portion of its insertion into the *dorsum* of the 5th metatarsal bone at the base is most uncommon. The significance of this insertion is not quite clear, although to some extent it may have acted as a compensation for the absence of peroneus tertius. The smallest slip (which joined the common extensor tendon to the 5th toe) is representative of the *peroneus quinti digiti*, while the prominence of the *abductor ossis metatarsi quinti* may have had reference to the small size of the slip which occupied the true insertion of peroneus brevis.

6. The following irregularities were noted in the feet of a subject prepared for anatomical demonstrations:—

- (a) The FLEXOR BREVIS DIGITORUM muscle sent no tendon to the 5th digit in either foot.
- (b) The FLEXOR ACCESSORIUS muscle of the right foot sent a strong tendon forwards, subjacent to the two innermost tendons of the flexor longus digitorum, to be inserted into the metatarsal ligament on the plantar aspect of the head of the 3rd metatarsal bone. Another tendon, very much smaller in size, and carrying a few muscular fibres from the accessorius, was continued forwards, and inserted into the plantar aspect and tibial side of the base of the first phalanx of the little toe. In the left foot, a slender muscular slip arose from the outer border of the flexor accessorius, and terminated in a fine tendon which joined the tendon of the flexor longus digitorum proceeding to the little toe.

In the same subject, *only the innermost lumbrical muscle was present* on each foot, while the three outer muscles were absent. In each case the nerve supply of the muscle which remained was derived from the second digital branch of the internal plantar nerve.

7. *Musculus sternalis.*

In an aged female subject, a well developed specimen of this muscle was found on one side only, namely, the left. At its

lower end, tendinous fibres blended with the aponeurosis of the obliquus externus abdominis, below the sixth costal cartilage, while others were very definitely attached to the fifth costal cartilage. As the muscle was traced upwards it lay anterior to the sternal ends of the costal cartilages, from the second to the sixth inclusive, and attained a maximum width of 15 mm. At its upper end it presented the following very definite tendinous attachments: (1) a strong slip ran almost vertically upwards, and blended with the sternal origin of the sterno-mastoid muscle of the same side; (2) two slips (one of which was very delicate) crossed obliquely in front of the manubrium sterni, and fused with the sternal origin of the opposite sterno-mastoid; (3) a short strong slip was attached to the anterior surface of the manubrium sterni. The two sterno-mastoid tendons were connected with each other by a tendinous band which crossed the supra-sternal notch.

The relationship of the anterior cutaneous terminations of the intercostal nerves to the sternalis muscle were as follows:—No. 1 emerged between the two tendinous slips which crossed to the opposite sterno-mastoid; Nos. 2 to 6, inclusive, appeared internal to the sternalis muscle; Nos. 7 and 8 pierced the inferior tendinous expansion of the muscle. After their emergence the whole of these nerves turned outwards, superficial to the sternalis muscle, and a fine filament from No. 6 entered the anterior surface of the muscle close to the inferior tendon. On examining the deep surface of the muscle, the following observations were made: (1) several fine filamentous tendons, continuous with muscular fasciculi of the pectoralis major, ran into and blended with the sternalis; (2) a strong nerve-twist from the third intercostal nerve entered immediately into the deep aspect of the sternalis.

There is no doubt whatever that the two nerves above described (No. 3 and No. 6) supplied the muscle, but from their size they were clearly insufficient for this purpose. Another and much larger nerve was seen to arise by two roots,—one from the anterior division of the *upper trunk* of the brachial plexus, and the other from the anterior division of the *middle trunk* of the same plexus. This nerve descended downwards and forwards, following very closely the line of the

third rib; and having pierced the pectoralis major, it was traced to within half-an-inch of the outer border of the sternalis muscle, where its large size and its blunt end showed quite conclusively that it had been accidentally cut by the dissectors who were removing the deep fascia from the pectoralis major. As it lay on the surface of the pectoralis major, one would have expected to be able to follow it quite easily for several inches further, but at the same time nothing was found which could be regarded as the continuation of this nerve.

So much has already been written, and so much diversity of opinion exists regarding the true homology of the sternalis muscle, that it is scarcely necessary to do more than record the foregoing facts, and leave them to speak for themselves. There is no doubt that—in the present case—this muscle was supplied, at least in part, by the third and sixth intercostal nerves; there is a supposition that it *may* also have received one of the anterior thoracic nerves, which in its origin was an *external* anterior thoracic nerve. No doubt there is a large body of evidence, based on the value of nerve supply, which points to the sternalis muscle being a rotated portion of the pectoralis major, but the occurrence of an intercostal nerve supply cannot be disregarded, although it be less frequent than the other, and it is quite possible that the sternalis may not in every instance represent the same supposed homology. It may even in some cases represent more than one source of muscular fibres.¹

II.—ABNORMAL ARRANGEMENTS OF NERVES.

1. *Large Cardiac Branch from the left Superior Laryngeal Nerve reaching the Superficial Cardiac Plexus independently.*

In this case the left superior laryngeal nerve had its usual origin from the ganglion of the trunk of the pneumogastric nerve, but was somewhat larger than the average. It gave off the external laryngeal branch at the usual place, but at this

¹ A summary of the literature on this subject is given up to date in a paper by Dr Wallace in *Jour. Anat. and Phys.*, vol. xxi. p. 158. Since then papers have appeared in the same *Journal* by Cunningham, vol. xxii. p. 391; Shepherd, vol. xxiii. p. 303; and Parsons, vol. xxvii. p. 505.

point another large branch arose. This nerve descended vertically behind the carotid sheath, and having entered the thorax, it passed in front of the aortic arch, at the lower border of which it was joined by a branch from the inferior or recurrent laryngeal nerve, and thereafter it entered the superficial cardiac plexus. No other cardiac branch from the left vagus was seen to cross the aortic arch, while two cardiac branches were traced behind the aortic arch to the deep cardiac plexus.

The nerve just described is no doubt an unusual variety of what is called in the rabbit the *depressor nerve*. In man, this nerve is supposed to arise in common with or just below the superior laryngeal nerve, and either to return to the vagus trunk as far as the lower part of the neck, or to join the superior cardiac branch of the sympathetic, for transmission to the cardiac plexus.

2. *A small Twig from the trunk of the Obturator Nerve to the Pectineus Muscle.*

In this case the usual branch from the anterior crural nerve entered the anterior surface of the upper part of the pectineus muscle, but when this muscle was reflected, another nerve was found entering the lower part of the muscle on its deep aspect. This twig took origin from the trunk of the obturator nerve, immediately in front of the obturator externus muscle, and descended anterior to the adductor brevis, to its point of entrance into the pectineus. At this spot the pectineus and adductor longus muscles were connected to each other by a fibrous arch, to which the fibres of both muscles were attached. Thus, although performing the function of an *accessory obturator nerve*, the twig in question did not follow the course usually associated with the small nerve of that name.

3. *Extension of the distribution of the Posterior Interosseous Nerve to Metacarpo-phalangeal articulations.*

The occurrence of this condition is not unknown in human anatomy, but it is of sufficient rarity to warrant a repetition of the record of its appearance, more especially as it was found in both hands of the same subject.

In the right limb, the posterior interosseous nerve divided into two parts on the posterior aspect of the interosseous membrane, an inch above the lower end of the radius. These passed downwards to the back of the carpus, under cover of the posterior annular ligament. Junctions were established between the two branches, which also supplied numerous twigs to the radio-carpal and carpal articulations. Besides these, two long and slender filaments were prolonged downwards, superficial to the second and third dorsal interosseus muscles. The filament in relation to the second interosseous muscle terminated at the proximal end of the interosseous space by dividing into fine threads, which pierced the dorsal interosseous muscle, and entered the adjacent carpo-metacarpal articulations. There was not sufficient evidence that they supplied any part of the muscle.

The filament in relation to the third interosseous space was traced to the distal end of that interval, where it ended in very fine threads, which supplied the third and fourth metacarpophalangeal articulations.

In the left limb, the posterior interosseous nerve presented a distinctly elongated swelling subjacent to the posterior annular ligament. From this enlargement a number of branches arose, from several of which finer twigs were traced to the radio-carpal, carpal and carpo-metacarpal articulations; in particular, two slender filaments were traced downwards, superficial to the third and fourth dorsal interosseous muscles. These nerve filaments were traced to the third and fourth metacarpophalangeal articulations, but there was no evidence of their supplying either muscular or cutaneous offsets.

In both of the hands under consideration the profunda branch of the ulnar nerve in the palm supplied the *radial* as well as the ulnar heads of the flexor brevis pollicis muscle. The branch for the radial head of the muscle passed outwards subjacent to the tendon of flexor longus pollicis, and entered the muscle in its *distal* half. At the same time the median nerve delivered a twig to this muscle in the usual place and manner.

4. *Five Digital Branches from the Internal Plantar Nerve.*

In this foot the internal plantar nerve supplied five digital branches, which were distributed to four and a half digits, only the fibular side of the little toe being unprovided with a branch from this nerve. The external plantar nerve supplied its normal number of digital branches, viz., two, and these occupied their customary places, so that the adjacent sides of the fourth and fifth digits were provided with a double set of plantar cutaneous nerves.

5. *Double Nerve Supply to the First and Second Dorsal Interosseous Muscles of the Foot.*

In the foot referred to in the preceding paragraph, the dorsal interosseous muscles were provided with the usual branches from the external plantar nerve, but in addition, the anterior tibial nerve supplied branches to the two innermost of the dorsal interosseous muscles. The inner division of the anterior tibial nerve supplied a branch to the first dorsal interosseous muscle while the second dorsal interosseous muscle received a branch which descended from the outer division of the anterior tibial nerve subjacent to the extensor brevis digitorum. This condition has already been recorded by Rüdinger and Cunningham.

6. *Absence of the Nerve of Wrisberg, and presence of a lateral cutaneous branch from the first intercostal nerve.*

The occurrence of the first variation is well known, and my reason for referring to an instance of this condition, which recently came under my notice, is to associate with the absence of this small nerve, the presence of a well marked lateral cutaneous branch from the first intercostal nerve. This association is of interest, as illustrating the compensatory value of one irregularity in the presence of another, more especially as the nerve of Wrisberg is derived from the first dorsal nerve.

III.—ABNORMAL LIGAMENT, *consisting of Cruciform Fibres in front of the anterior common ligament of the elbow-joint.*

Last winter session I observed a stratum of ligamentous fibres lying superficial to and quite distinct from the anterior common ligament of an elbow-joint, which had been very carefully prepared by the prosectors to the class. These fibres were arranged in the form of two flat bands, which decussated with each other, and had the following attachments:—one band extended from the front of the internal condyle of the humerus outwards and downwards to the orbicular ligament; the other extended from the front of the external condyle downwards and inwards, to the front of the coronoid process of the ulna.

IV.—ARTERIAL ABNORMALITIES.

1. *A Right Bronchial Artery arising from the aortic arch.*

The artery in question was an auxiliary vessel to the ordinary bronchial artery for the right lung, which arose from the first right aortic intercostal artery.

The auxiliary bronchial artery arose from the posterior surface of the aortic arch immediately below the interval between the innominate and left common carotid arteries. Inclining downwards and backwards, it traversed the anterior surface of the trachea, on the left side of which it continued to descend until it reached the root of the left bronchus. At this point it turned towards the right side in front of the left bronchus, and crossing the angle between the two bronchi it broke up into several branches on the *front* of the right bronchus. Each of these accompanied a branch of the bronchus into the substance of the right lung.

The left lung was only provided with one bronchial artery, which arose from the front of the descending thoracic aorta.

2. *Origin of the Long Thoracic, Posterior Scapular, Suprascapular and Superficial Ascending Cervical Arteries by a Common Trunk from the Axillary Artery.*

This combination of variations occurred on the left side of a subject in which the absence of the last three vessels from the

subclavian trunk formed a marked feature of the dissection of the posterior triangle of the neck. As the dissection advanced it was found that each of the four vessels referred to occupied the ultimate position associated with and indicated by its name, but that they had all sprung from a common trunk arising from the axillary artery. This trunk took origin from the lower border of the first part of the axillary artery, and passed downwards upon the surface of the serratus magnus muscle. Before it had quite reached the lower border of the second rib, it bifurcated into two parts of unequal size. The smaller of the two continued onwards, and fulfilled the distribution associated with the long thoracic artery, while the larger vessel turned abruptly towards the chest wall, and coursing upwards, left the axilla by passing between those digitations of the serratus magnus arising from the first and second ribs. Still pursuing its course upwards and backwards behind that part of the serratus magnus arising from the first and second ribs, it approached the superior angle of the scapula, where it distributed as a collateral branch, the posterior scapular artery. Then turning outwards along the superior scapular border, it gave off the superficial ascending cervical artery, under cover of the trapezius muscle, and finally distributed its terminal branch as the suprascapular artery, which entered the supra-spinous fossa above the suprascapular ligament.

3. *Double Profunda Femoris Artery.*

The above peculiarity was seen in the dissection of a left thigh; and as the condition is a rare one, the following account of the two arteries may be of interest. The vessels may be distinguished from each other by the terms *profunda femoris superior* and *profunda femoris inferior*.

Profunda femoris superior was given off from the outer and back part of the femoral artery, immediately below Poupart's ligament. It ran downwards and inwards behind the femoral trunk, where, one inch and a half from its commencement, it gave off the external and internal circumflex arteries in a perfectly normal manner. Two inches lower down the *profunda femoris superior* supplied the *first perforating artery*,

which passed through the upper part of the tendon of adductor brevis, posterior to which it supplied a muscular branch to the adductor magnus, and then perforated the tendon of this latter muscle close to the femur. The terminal branch of the profunda femoris superior perforated first the lower part of the adductor brevis tendon, and then the tendon of the adductor magnus, becoming in fact the *second perforating artery*.

Profunda femoris inferior arose from the inner side of the femoral trunk, three inches below the point of origin of the profunda femoris superior, which it equalled in size. It coursed downwards, lying alongside of the femoral artery, and not accompanied by a special vein. On reaching the front of the adductor longus, it passed backwards through the tendon of that muscle, behind which it gave muscular branches to the adductor magnus, whose tendon was pierced by another branch representing the *third perforating artery*.

The terminal branch of this inferior profunda femor is continued downwards between the tendons of the adductors longus and magnus, supplying muscular branches to the latter, and ultimately piercing its tendon close to the femur, thus forming the *fourth perforating artery*.

Bifid Auricular Appendix and a Moderator Band in the Left Auricle.

These unusual variations were found in the heart of an adult male which did not present any evidence of valvular disease, and, beyond the abnormalities mentioned, there was nothing else which attracted special attention.

The auricular appendix had its customary position, but instead of being notched to the usual extent, it was deeply cleft, so as to present the appearance of two appendices. The smaller of the two divisions was nearest to the left side. The interior surface of each presented the characteristic muscoli pectinati. The pulmonary veins from the right lung entered the auricle by two orifices, while those from the left lung had united into a common trunk, and thus presented one orifice of entrance into the auricle.

In the cavity of the auricle there was a distinct moderator band, of a thickness resembling whipcord. Its upper end was attached to the auricular wall immediately above and in front of the orifice of the left pulmonary vein; the lower end was attached to the inter-auricular septum between the position of the fossa ovalis and the mitral orifice. This lower end gave off some fine fibrils, of which a few became continuous with the auricular aspect of the base of the anterior cusp or segment of the mitral valve. The removal of the endocardium demonstrated the continuity of this moderator structure with the heart substance.

In the pages of the April number of this *Journal*¹ three instances of this abnormality are recorded.

In Dr Rolleston's case there were certain points of resemblance to the one above described, but it differed chiefly in regard to the septal attachment of the band. The heart was otherwise natural.

In the case described by Professor Wardrop Griffith the band extended between the "left anterior wall $\frac{3}{4}$ inch above and behind the opening of the auricular appendix," and "the anterior part of the valve of the foramen ovale," which was completely closed.

Dr J. K. Fowler's case, originally described in the *Pathological Society's Transactions*, 1882, "was attached to the septal wall, to the inner side of the annulus ovalis, and was continuous with the membrane forming the fossa ovalis," which presented a valve-like opening.

The two latter cases certainly very closely resemble each other, while my case is more akin to that of Dr Rolleston.

If we are to regard these bands as exaggerated varieties of normal fibro-muscular bands passing from the valve of the foramen ovale to the auricular wall, then the present case provides a very extreme form of the condition in which it has ceased to have immediate association with the foramen ovale.

¹ *Proc. Anat. Soc.*, p. v. ; and *Jour. Anat. and Phys.*, April 1896.

Notices of New Memoirs.

La Suture Métopique et ses Rapports avec la Morphologie Crânienne.
By Dr G. PAPILLAULT. Paris, 1896.

DR PAPILLAULT has contributed to the *Mémoires de la Société d'Anthropologie de Paris*, t. ii. (iii^e série, 1^{er} Fascicule), an important essay on the metopic condition of the frontal bone. His investigation has been conducted in the Laboratory of Anthropology, Paris. He has come to the conclusion that a persistent frontal suture is due to a greater cerebral development, and that the cause of metopism is to be looked for in the brain itself. The general pressure of the brain against its enveloping structures is greater in metopic skulls. This does not necessarily affirm that metopic persons are intellectually superior to those in the same race who have the frontal suture closed, but that the relative weight of the brain is greater. In 807 male crania in the laboratory, 9·91 per cent. of the skulls were metopic; in 329 female crania, 11·85 per cent.; but Ferraz de Macedo states that in 1000 cotemporary Portuguese, the proportion was 11·8 in the men and 9·3 in the women.

Anthropology of the Todas and Kotas of the Nilgiri Hills, and of the Brahmans, Kammálans, Pallis, and Pariahs of Madras City.
By EDGAR THURSTON, Superintendent, Madras Government Museum. 1896.

THIS memoir forms bulletin No. 4 of the publications of the Madras Government Museum. It is principally devoted to an account of the very interesting races of the Nilgiris known as Todas or Tudas, and Kotas. An excellent description is given of Toda customs and ceremonies. The physical characters of the people are described, and the external measurements of the body, together with the colour of the skin and hair, and the abundance of the hair on the head and face. No skeletons or skulls of the Todas seem to have been collected; as the practice of burning the bodies of the dead necessarily injures or destroys the bones. The average height of the Toda men who were measured was 169·6 cm., the maximum being 179, and the minimum 159·2. The mean cephalic length was 194 mm.; breadth, 142 mm.; and index, 73·3. The average nasal height was 47 mm.; breadth, 36 mm.; index, 74·9. The women had a mean height 155·6

cm., the maximum 165·6, the minimum 146·5 cm. The mean cephalic length was 184 mm.; breadth, 136 mm.; index, 73·9. The average nasal height was 42 mm.; breadth, 32 mm.; index, 75·5.

A corresponding series of observations were made on the customs, ceremonies, physical characters, and external measurements of the Kotas. The Kotas are not so hairy as the Todas; their mean height is less (162·9), being 6·7 cm. below the Todas; they are not so muscular and strong, have broader hips, and shorter and narrower feet. Both Todas and Kotas are dolichocephalic; the cephalic index is almost the same in both. The Kotas have wider faces, with more prominent cheek bones, a greater bimalar breadth, wider lower jaw, and more developed zygomatic arches. The Toda nose is slightly longer and broader than that of the Kotas. Corresponding to the greater length from the vertex to the tragus, and the more developed frontal region, the facial angle (Cuvier) of the Kota 70° is 3° in excess of that of the Toda (67°).

The average height of a series of the Madras Brahmans measured during life was 162·5 cm.; the cephalic index was 76·4; the nasal index 77·2; the facial angle 69° . The average height of several Kammálans was 159·7; the cephalic index was 75; the nasal index, 77·3; the facial angle, 70° . The average height of the Pallis measured was 162·5; the cephalic index was 73; the nasal index, 77·9; the facial angle, 69° . The average height of the Pariahs measured was 162·1; the cephalic index was 73·6; the nasal index was 80; the facial angle was 68° .

Preliminary Note on the Occurrence of a Placental connection in Perameles Obesula and on the Foetal Membranes of Certain Macropods. By JAS. P. HILL, *Demonstrator of Biology, University of Sydney.*

MR HILL gives an account (*Proc. Linnean Socy. of New South Wales*, vol. x., 2nd series, Nov. 27, 1895, of the gravid uterus of *Perameles obesula*. Three embryos were found in the right uterus, and two in the left. The foetal membranes have essentially the same general arrangement as those described by R. Semon in *Phascolarctus* and *Æpyprymnus*. The embryo is sunk in the yolk sac, and is partially surrounded by the invaginated upper portion of the wall of that sac, the "inneres Blatt" of Semon. This inner leaf does not so completely surround the embryo as in *Phascolarctus*, *Æpyprymnus*, and *Macropus*, so that the portion of the serous membrane consisting of ectoderm and somatic mesoderm, and limiting the extra-embryonic coelom, externally forms a discoidal area, with which area the allantois fuses, and over it the placental connection is established. The allantois consists of a long somewhat flattened stalk and a terminal expanded flattened vesicle. The stalk leaves the embryo behind the yolk sac, and bend-

ing to the right, expands at its distal end into the flattened vesicle which spreads over the discoidal area. The vesicle and stalk are lined by endoderm cells. The mesoderm of the outer surface of the allantois fuses with the somatic mesoderm of the serous membrane, and the mesenchyme on the outer aspect of the allantoic cavity apparently stands in direct connection with the uterine mucosa.

The uterine mucosa had apparently lost the columnar epithelium through degeneration. A short distance below the surface of the mucosa were groups of large oval or rounded nuclei, which, the author thinks, were derived from proliferation of the uterine epithelium. The uterine glands were well developed, and their epithelium was not degenerated. The placenta received the foetal blood from two small arteries which accompanied a large vein. They extended unbranched in the allantoic stalk: they branched on the inner surface of the vesicular allantois, and could be traced into capillaries in the mesenchyme of the outer surface, which were closely applied to the uterine mucosa, and formed with it an interlocking system with the maternal capillaries. The author concludes that a true allantoic placenta exists in *Perameles*, so that the Marsupialia can no longer be included among the Aplacentalia as not possessing an allantoic placenta.

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PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

NOVEMBER 1895.

THE Ninth Annual General Meeting of the Society was held on November 22, in the Court-Room of Guy's Hospital. Present—Mr LOCKWOOD (Vice-President) in the chair, twenty-two members, and four visitors.

The minutes of the previous meeting were read and confirmed.

The following gentlemen were elected officers for the ensuing year:—*President*—G. D. Thane. *Vice-Presidents*—Johnson Symington, M.D.; R. W. Reid, M.D.; C. B. Lockwood. *Treasurer*—G. B. Howes. *Secretaries*—A. F. Dixon (Ireland); J. Yule Mackay, M.D. (Scotland); F. G. Parsons (England). *Council*—W. Anderson, D. J. Cunningham, F.R.S.; E. Fawcett, M.B.; P. Flemming, M.D.; A. Hill, M.D.; R. Howden, M.D.; A. A. Kanthack, M.D.; A. Keith, M.D.; R. Clement Lucas, M.S.; G. H. Makins; T. H. Openshaw, M.S.; A. M. Paterson, M.D.; A. Robinson, M.B.; H. D. Rolleston, M.D.; T. W. Shore, M.D.; E. Barclay Smith, M.D.; J. H. Targett; A. Thomson, M.D.; G. R. Turner; B. Windle, M.D.

Professor THANE then took the chair, and thanked the Society for the honour conferred upon him.

A vote of thanks to Professor D. J. Cunningham, the past President, was carried unanimously.

The Treasurer's Report, showing a balance of £76, 2s. 6d., was received and adopted.

In presenting his Annual Report, the TREASURER said that the financial feature of the year had been the final recovery of subscriptions long in arrear, and that the percentage of subscriptions received for the current year had far exceeded that of previous occasions. After referring to the progress of the Index to the *Journal of Anatomy and Physiology*, he pointed out that, although during the year 1894–1895 the Society's activity had increased, the expenditure was still insufficient as compared with that of the years 1891–1893, during which the number of members was smaller than at present. He remarked that within the last year there had been eleven enrolments and but three resignations, and reiterated the opinion that, as judged by the expenditure, the work of the Society was not making sufficiently rapid progress.

The following alteration of Rule III. was submitted by the Council and carried :—To cancel all the words after “be,” and to insert “submitted to the Committee of Management, and on their recommendation the ballot shall take place at the next meeting of the Society.”

Messrs Hubert Higgins and G. S. Farmer, M.B., F.R.C.S., were elected members of the Society.

Dr G. F. BLACKER read a paper on the *Topographical Anatomy of the Fourchette*. The paper is printed in the *Journal of Anatomy*, January 1896. Dr Blacker points out the difference of opinion which exists among anatomists as to the relation of the fourchette to the labia majora and minora. The first part of his paper consists of a review of the literature of the subject; the second, of a record of observations on 397 out-patients. These records show that in about 15 per cent. the fourchette was formed by the united posterior extremities of the labia minora, while in the rest it was a fold of skin apparently uniting the posterior extremities of the labia majora. Dr Blacker takes the view that the fourchette is really a part of the labia minora; he advocates the abolition of the terms “anterior and posterior commissures.”

Mr F. G. PARSONS read a paper and exhibited drawings of a *Rare Form of Parasitic Fœtus*. The paper will be found in the *Journal of Anatomy*, January 1896. The parasitic fœtus is represented by an extra arm and leg on the left side of the original fœtus, both of which are double, and consist of two arms and legs united on their flexor surfaces. There are also traces of two kidneys and a bladder of the parasitic fœtus, as well as an extra auricle.

There are many abnormalities in connection with the abdominal viscera and the vascular, muscular, and nervous systems.

The primary fœtus is anencephalous, but no m. sternalis was found.

Dr ARTHUR KEITH read a paper upon *The frequent occurrence of a Divided Inferior Vena Cava in the genus Hylobates* (Gibbons). In European literature he knew of only five recorded dissections of gibbons. Three were by Kohlbrügge ⁽¹⁾, one by Deniker ⁽²⁾, and the other by Th. L. W. Bischoff ⁽³⁾. Deniker's animal was a fœtus; he remarked that the inferior vena cava was very short; the two other authors merely noticed that the arrangement of abdominal veins resembled that of man. Mr Keith had records of dissections of nine gibbons, but only in six had the condition of the abdominal veins been recorded. Three of these were of the species *lar*, three of *pileatus*. In four animals out of the six—two in each species—three of these four were females—the vena cava was divided in the region posterior to the kidneys. The right vein arose on the dorsal surface of the right common iliac artery by the junction of the external and internal iliac veins. It joined the right renal vein, and received the ovarian. The left vein arose in a manner similar to that on the right, it received the left ovarian vein and joined the left renal. The left renal passed in two cases behind the aorta ⁽⁴⁾, in two cases in front of the aorta to join the right renal, and thus formed the vena

cava. A connecting vein between the common iliacs in the region of the sacrum was not observed, but it may have been present. The connections of the right and left veins with the venæ azygos were not noted.

Kollmann has found about thirty cases of this arrangement of veins recorded as having occurred in man. Mr Keith thought it occurred more frequently than such a small number suggested—probably as frequently as once in 150 bodies.

Hochstetter (⁴), the authority upon the morphology of veins of the trunk, had pointed out that a divided cava occurred both in the *Ornithorhynchus* and *Echidna*. The speaker had been able to verify that in two specimens of the duckbill. Hochstetter had further pointed out that the vena cava occurs in a divided form amongst dolphins, seals, and frequently also in the hedgehog, cat, and rabbit. Out of fifty catarrhine monkeys Mr Keith had not found any case of divided inferior cava.

Mr Keith thought it was interesting to find a variation that occurred not unfrequently in man occurring so frequently in an animal that was nearly allied to man. It was still more interesting when taken in connection with some other structural variations which occur in man and the gibbon. The contrast was best made in a tabular form:—

	<i>Man.</i>	<i>Gibbon.</i>
Divided inferior vena cava,	Rare.	Common.
Manubrium enlarged by addition of the first piece of the meso-sternum.	Very rare.	Very common.
Head to biceps cubiti from the small tuberosity of humerus.	Rare.	Very common.
Head to biceps cubiti from internal inter-muscular septum of brachium.	Rare.	Common.

Amongst gibbons the divided inferior vena cava occurs most frequently amongst females; this is probably also the case in the human race. The usual persistence of the right cardinal vein as the entire vena cava may be connected with the lower position of the right kidney; at anyrate, in the case of a left inferior vena cava, and often in the cases of divided inferior venæ cavæ, the left kidney was lower than the right.

Keith was still uncertain that Hochstetter had settled the morphology of the inferior vena cava. He quite agreed with that eminent anatomist that the præ-renal part of the inferior vena cava represented the venæ revehentes of the lower vertebrata, but he was doubtful if the post-renal parts represented cardinal veins only. In the first place, the venæ advehentes of lizards were often directly connected with the venæ revehentes by a connecting trunk that thus “short-circuited” the blood straight from the tail to the heart without passing

through the kidneys. The venæ advehentes in such a case are certainly not cardinals. They occupy the position occupied by an inferior divided vena cava. These veins lie on the ventral aspect of the aorta and iliac arteries, and in some Marsupials the inferior vena cava occupies such a position. Besides, the renal veins—as do the venæ advehentes—lie on the ventral aspect of the renal arteries, and he did not think—from a morphological point of view—that the explanation Hochstetter gave of how the cardinal veins came to occupy that position in mammals was satisfactory. Further, the caudo-renal system of veins in the *Reptilia* had to be accounted for in the mammalia. From their position the ascending lumbar veins seemed to him rather to correspond to the cardinal veins. He mentioned these doubts merely to act against a too hasty acceptance of Hochstetter's views.

Mr PARSONS showed a drawing of a double inferior vena cava found in the St Thomas's Hospital dissecting-room, in a male subject.

Mr BLACK also referred to two cases in man.

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(3) BISCHOFF (Th. L. W.), "Beiträge zur Anatomie des *Hylobates leuciscus*," *Abh. bayer. Ak. Munchen*, Bd. x., 1870.

(4) HOCHSTETTER (F.). *Morph. Jahrbuch*, 1893, Bd. xx. pp. 542-648. He gives a full list of references to his other papers, and also to all the literature bearing upon the Embryology and Morphology of the Abdominal Veins.

(5) FROBIEP. *Anat. Anzeig.*, Bd. x. No. 18, p. 574. Records four cases out of twenty-eight human bodies in which the left renal vein passed behind instead of in front of the aorta.

Mr HUBERT HIGGINS read a paper on *The True Capsule of the Knee*, which is printed *in extenso* in the *Journal of Anatomy*, January 1896. In it he describes the true capsule as separated from the fibrous expansions of the vasti by a multilocular bursa; elsewhere the true and accessory capsules are separated by loose connective tissue.

In about two per cent. of cases the true capsule is unconnected with the subcrureus bursa.

In those cases in which the ligamentum mucosum is represented by a septum, it usually consists of two layers which split to inclose the crucial ligaments, being attached above and below to the periphery of the articular cartilage of the tibia and femur.

Mr Higgins regards the more ordinary form of the true capsule as the remains of the two capsules limiting the original internal and external articulations, the anterior part having become obliterated. The extracapsular positions of Humphry's and Wrisberg's ligaments he looks upon as evidence of the extracapsular origins of the semilunar cartilages.

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

FEBRUARY 1896.

AN Ordinary Meeting of the Society was held on Monday, February 10th, at St Mary's Hospital Medical School,—Professor THANE in the chair.

Twenty members and visitors were present.

The following gentlemen were elected Members of the Society.

1. R. H. BURNE, 146 Gloucester Terrace, Hyde Park, W., proposed by F. G. Parsons, P. Flemming, A. Keith; 2. R. J. BERRY, M.D., 4 Howard Place, Edinburgh, proposed by J. Musgrove, J. Symington, P. Flemming; 3. J. H. FISHER, M.B., B.S., Demonstrator of Anatomy at St Thomas's Hospital, proposed by F. G. Parsons, A. Keith, P. Flemming; 4. E. T. E. HAMILTON, M.D., Demonstrator of Anatomy at Guy's Hospital, proposed by G. H. Makins, A. S. Grünbaum, F. G. Parsons; 5. J. H. SEQUEIRA, M.D., Demonstrator of Anatomy at the London Hospital, proposed by T. H. Openshaw, A. Keith, P. Flemming; E. M. CORNER, B.Sc. Lond., St Thomas's Hospital, proposed by W. Anderson, G. H. Makins, F. G. Parsons.

Dr ROLLESTON showed a *Band in the left Auricle of the Heart* of a boy aged $1\frac{1}{3}$ year; it was a round fibrous band, crossing over the orifice of the mitral valve. It was attached to the outer wall of the auricle below and behind the appendix (now removed), and ran downwards and to the right, to be attached to the septal wall of the auricle below, and in front of the fossa ovalis. Its attachment to the septal wall was not blended with the annulus ovalis or fenestrated.

There was no slit in or abnormality of the fossa ovalis, and in other respects the heart was natural.

There was a Meckel's diverticulum on the ileum.

Dr J. K. FOWLER, in the *Pathological Society's Transactions*, 1882, p. 77, had recorded a somewhat similar though larger band in the left auricle of a man aged 42.

The band in that case was $\frac{3}{4}$ inch wide, with its edges vertical. It was attached to the septal wall, to the inner side of the annulus ovalis, and was continuous with the membrane forming the fossa ovalis. This attachment showed fenestrations. The foramen ovale presented a valve-like opening.

Dr Fowler regarded this band as an overgrowth of the valve closing the foramen ovale, which had become directed by the blood-stream towards the outer wall of the auricle, and had become adherent there.

In the present case the attachments of the band to the septal wall were different, and the foramen ovale had closed properly. The band

could be explained as the result of elongation of abnormal adhesions between the outer wall of the auricle and the part of the auricular septum formed by the endocardial cushions. But there was nothing to show why such pathological adhesions should have formed.

Professor WARDROP GRIFFITH showed a *Heart with a fibro-muscular Band* passing across the cavity of the left auricle. The heart was somewhat enlarged, and its cavities were dilated; there was old-standing thickening of the segments and cordæ tendineæ of the mitral valve, with very slight stenosis. The pericardium was universally adherent. The cause of death was unassociated with the cardiac condition.

The band (fig. 1) started from the anterior part of the valve of the foramen ovale (which was completely closed), and passed forward and



to the left across the cavity of the auricle, blending with the left anterior wall $\frac{3}{4}$ inch above and behind the opening of the auricular appendix. In the natural position of the heart its surfaces were directed respectively upwards and backwards, and downwards and forwards. At its narrowest part it was $\frac{1}{2}$ inch wide, and towards its attachments it expanded in a fan-like manner. Its lower or posterior margin was continuous to the left with the posterior auricular wall, and to the right with the valve of the foramen ovale at its anterior part, backward across the middle of which it was then continued as a frænum. The anterior or upper margin, when traced to the left, swept forward, and ended by bifurcating and becoming continuous with the auricular wall. Close to the termination of this edge a small oval aperture existed in the band, which admitted the passage of a large crow-quill. When the anterior margin was traced to the right it bifurcated where the band began to expand, and the two limbs,

sweeping respectively forward and upwards, and forwards and downwards, blended with the auricular wall in front of the closed foramen ovale. Between these two limbs was a triangular space, floored by a thin membrane separating the left from the right auricle, and this, in the light of what is to follow, represents the fibrous tissue of the annulus ovalis.

The band, which was about as thick as a piece of notepaper, was mainly fibrous, but presented muscular fibres, scattered chiefly on its upper or posterior aspect, continuous to the left with those of the auricular wall, and to the right with muscular fibres which were spread over the valve of the foramen ovale. In its anterior margin was a small calcareous spicule.

By this band therefore the left auricle was cut up into two parts, a lower and larger communicating with the auricular appendix and ventricle, and an upper which received the pulmonary veins. These veins were damaged in removing the heart, but it was certain that the right and the left upper opened into the auricle above the band, while the ending of the left lower was not made out, but on this side there may have been only one vein.

Limited by the band and the auricular wall were two large deficiencies,—the anterior large enough to admit the passage of one's finger, the posterior that of one's thumb.

Note.—The above description was written after I had had the advantage of perusing the account of Dr Fowler's case in the *Patho-*

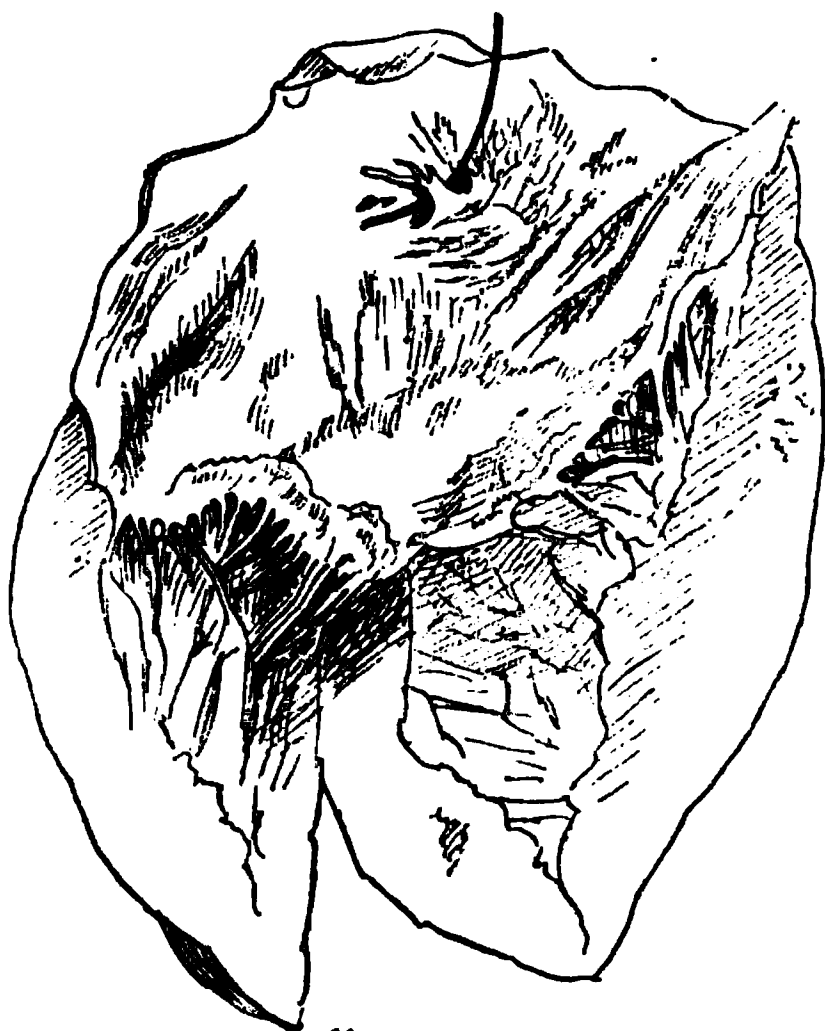


Fig 2

J. N. Haigh
an.

logical Transactions, for a reference to which I am indebted to Dr Rolleston's account of his specimen. I have no doubt Dr Fowler's explanation is the correct one, and my case very strongly resembles his. An inspection of the auricular septum from the left side will in

many cases, I find, show retinacula or bands continued forward from the valve of the foramen ovale, which are sometimes adherent to the auricular wall in their whole extent, but which are not infrequently separated by a small interval, through which one can pass a probe. Such an example I have had figured from a heart in my possession (fig. 2). This may occur with or without valvular patency of the foramen ovale. In the great majority of cases, I believe, muscular fibres will be found ramifying underneath the endocardium of the valve of the foramen ovale, and these are nearer to and better seen from the left auricle than the right.

In agreeing with Dr Fowler as to the interpretation of his specimen, I would suggest that in both instances we have to do with an exaggeration of a state of affairs very frequently met with, and not usually regarded as abnormal, such as is shown in fig. 2. In the two diagrams bristles are represented as passing round structures which I regard as essentially identical, both being fibro-muscular bands passing from the valve of the foramen ovale to the auricular wall.

The calcareous spicule referred to, I regard as an evidence of the same degenerative process that is indicated by the condition of the mitral segments.

Some Processes of the Occipital and Mastoid Regions of the Skull.

Mr E. M. CORNER examined the conditions found in 152 skulls. In 93 per cent. a distinct process was found on the inner edge of the digastric fossa. Having thus established the presence of the process in man, skulls of the various animal groups were examined. This process was present in the apes as in man, and was very large in the skull of an orang. In the lemurs the inner lip of the digastric fossa is represented by a ridge, usually more on the occipital than on the temporal bone, and is continuous with the jugular process of the occipital bone. The summit is sometimes at one or other end of this ridge, and sometimes again in some intermediate position. Hence it seems that the two separate processes in man have arisen from a common ridge. An interesting proof of this is seen in the origin of the digastric muscle in the horse. Its inner part takes origin from the 'paroccipital' process. Hence this paroccipital process represents both processes in man. In the text-books the names 'paramastoid' and 'paroccipital' are applied indiscriminately to the jugular process of the occipital bone. As there is a constant and well-marked process on the inner lip of the digastric fossa, and this was probably derived from the same ridge as gave rise to the jugular process, I venture to propose that the name paroccipital be restricted to the jugular process, and the name paramastoid to the process on the inner lip of the digastric groove.

Mr E. M. CORNER read a paper on "*Some points in the Anatomy of the Elbow-Joint.*" The object of this paper is to homologise certain structures in the elbow with those in the knee. The elbow-joints of the ox, sheep, dog, cat, and man were examined, giving examples of the great types of elbows, with special reference to the following details :—

1. A fold of the posterior ligament of the capsule on its external part.

2. A semilunar fold on the inner side of the external lateral ligament.

3. The transverse fibres of the internal lateral ligament (Cooper's ligament), and a ligament on the outer side of the joint corresponding to it.

The postero-external fold of the capsule is shown to be homologous with the crucial ligaments of the knee, and is termed, after Macalister, the crucial fold. The semilunar fold on the external lateral ligament is homologous with the internal fibro-cartilage of the knees, and another fold internal to the lower end of the crucial fold is homologous with the external fibro-cartilage.

These three folds were shown in the sections of the elbow of a third month's human foetus.

Mr E. M. CORNER read a paper on the *Temporal Fossa*, in which was shown the relations existing between variations of the temporal fossa and the cephalic, vertical, and gnathic indices. The length, height, and least bitemporal breadth of the fossa were first calculated in ratio of the length, height, and breadth of the skull respectively; but the results of this method were not definite enough to warrant any conclusions being drawn. Sir William Flower's method was then adopted, of calculating the measurements to the basinasal length. The indices used were of the general form—

$$\frac{\text{Measurement} \times 100}{\text{basinasal length.}}$$

In this way three indices were obtained for each curved line, viz., length, breadth, and height indices.

By this means it was shown that dolichocephaly and tapeinocephaly lower these indices, brachycephaly and akrocephaly having higher indices. Prognathic skulls, with their heavy jaw, would be expected to have relatively large temporal indices, but their indices fall between those of orthognathic and mesognathic skulls. This is probably due to the association of prognathism usually with a long and low skull, i.e., dolichocephaly and tapeinocephaly.

Examples were given of skulls which approach the simian type in the approximation of their temporal crests, and the indices for their respective races added. A hundred skulls in all were examined.

Dr J. H. SEQUEIRA showed a specimen of *Ectopia Vesicae* with patent vitelline duct. The lower end of the ileum communicated with the exterior by a wide funnel-shaped duct, which opened between the two halves of the extroverted bladder.

The right kidney was hypertrophied, and its ureter opened into the lower part of the right genital duct.

The left kidney was atrophic, and its ureter of small calibre was attached to but did not communicate with the genital duct. A perfectly natural ovary was present on each side. The genital ducts were dilated about the middle, forming distinct uteri on each side. Near the left kidney lay a small rounded body, which a microscopical examination showed to resemble an embryonic testicle.

Dr Sequeira thought that Mr Shattock's hypothesis, that ectopia

was due to a prolongation forwards and upwards of the proctodæum, received support from this specimen, which it is believed presents a condition never before described in this country. Ahlfeld mentions such a case, and figures a somewhat similar condition in his *Atlas*.

Dr BARCLAY SMITH read a paper on the *Astragalo-calcaneo-navicular Joint*. He pointed out that great confusion exists in the text-book descriptions of the ligaments connecting the os calcis and the astragalus, no definite plan being followed in respect to their arrangement; and, as a consequence, each author adopts a nomenclature of his own, and no two are in any way agreed.

He suggested that, for descriptive purposes, the ligaments in connection with the two joints existing between the os calcis and astragalus should be discriminated as far as possible. The anterior joint is one in which the navicularis plays a part, the os calcis with that bone helping to form a deeply-excavated socket in which the head of the astragalus rotates. The calcaneo-navicular ligaments should be described as contributing the formation of the socket, supplementing the bony surfaces where these are deficient. The ligamentous part is a necessity as a varying factor in the surface of the socket, owing to the curvatures of the head of the astragalus occupying it varying in different positions. The adaptation of the variable socket to the rounded head which occupies it is to a large extent influenced by a band which is lodged in the groove interrupting the anterior of the two astragalar facets on the os calcis; this band being connected with either the synovial covered pads of fat or the calcaneo-navicular ligament on the floor of the socket on the one hand, and with the head of the astragalus close to the articular surface on the other.

The head of the astragalus is retained within its socket by certain bands, which should be described as constituting the capsule of the joint. These bands consist of the astragalo-navicular ligaments on the dorsal aspect, internal and external astragalo-calcaneal ligaments on the lateral aspects, and the anterior fibres of the interosseous ligament in the posterior aspect of the joint.

The interosseous ligament is a much vaunted structure as far as its strength is concerned, but this is certainly open to considerable doubt. The appearance presented by the bony surfaces to which it is attached preclude the idea; and further, the canalis tarsi is largely occupied by a deeply-seated contingent of the ligamentum fundiforme, the fibrous loop which forms a pulley for the tendons of the extensor longus digitorum and peroneus tertius, a structure usually described in connection with the anterior annular ligament of the ankle. The ligamentum fundiforme was first described by Retzius, who, finding it in the dog, proved its existence in man, but his description seems to have escaped the attention of subsequent writers.

The foregoing papers are published *in extenso* in the *Journal of Anatomy and Physiology*, April, 1896.

Mr J. H. TARGETT exhibited several specimens of *congenital dislocation of the hip*, which showed the characteristic changes in the bones produced by that condition.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

MAY 1896.

AN Ordinary Meeting of the Society was held on Friday, May 15th at King's College,—Professor THANE in the chair. Twenty-eight members and visitors were present. The following gentlemen were elected members of the Society :—

(1) T. H. BRYCE, M.A., M.B., Lecturer on Anatomy in Queen Margaret College, University of Glasgow, proposed by J. Cleland, W. Turner, J. Yule Mackay.

(2) G. ELLIOT SMITH, M.D., Ch.M., late Demonstrator of Anatomy in the University of Sydney, proposed by J. T. Wilson, G. B. Howes, F. G. Parsons.

Mr ARTHUR KEITH exhibited *Organs from Dissecting-room Subjects which had been preserved with Formaldehyd*. The advantages claimed for this substance as a preservative of dissecting-room subjects were :—

(1) The soft organs of the body were preserved in their natural shapes and relationships, and retained approximately their natural colour and consistency.

(2) From the fact that formaldehyd led to the disappearance of all superfluous moisture in the loose tissues, organs like the pancreas, spleen, sympathetic nerves and ganglia, lymphatic glands and vessels, pelvic viscera, &c., which, in the ordinary methods of injection, lie in a condition of dirty liquidity, are cleanly preserved in a state fit for dissection. The blood is thrown into the veins, and

(d)

coagulated there by the injection, so that these vessels are as good as artificially injected; the nerves and membranes, like the arachnoid, dura mater, and intestinal wall, come out firm and white; it renders dissection a much more cleanly business than the ordinary preservatives.

The disadvantages were:—Its erosive action on the fingers; its biting effect on the nostrils, eyes, and throat of the dissector; but of these effects the students of the London Hospital had not complained. It rendered the muscles stiff and friable, so that the body could not be placed in the lithotomy position nor the arms widely abducted without rupturing some muscles. It preserved the brain extremely well when a portion of the solution was specially injected through the circle of Willis from the common carotid artery of one side. In the ordinary method of injecting the body from the femoral or carotid artery, the brain was not preserved unless this special injection was made. Mr Ockenden of the Zoological Gardens, however, objected to the use of formaldehyd for the preservation of brains, as it fixed the pia mater so firmly that it could not be removed without injury to the cortex.

Professor BLUM, who introduced formaldehyd as a hardening and preserving agent for microscopical specimens some three years ago, had given quite recently (*Anat. Anzeiger*, 1896, Bd. xi. p. 718) a full list of references to literature on the uses of the substance. At the beginning of last winter session Mr Dean of the London Hospital suggested to Mr Keith its use as a preservative for dissecting-room subjects, and it was only natural to expect that other anatomists had been experimenting with it for that purpose. It had not found much favour in America. Wilder, at a meeting of American Anatomists (*Med. Rec.*, Jan. 18, 1896), gives it a secondary place; Mall (*Anat. Anz.*, 1896, Bd. xi. p. 769) prefers the alcohol, glycerine and carbolic acid injection. In the *Anatomischer Anzeiger* (Dec. 1895, B. xi. p. 417) Gerota gives a favourable report after a year's experience with formaldehyd as a preservative for dissecting-room subjects. He used five litres of a 15 per cent. solution of the ordinary commercial solution for each body when he wished to cut the body in sections showing topographical relationships; the same amount of a 5 per cent. solution when the body was to be examined in the ordinary method by students.

Mr KEITH used a bottle of commercial formaldehyd (1 lb. of a 45 per cent. solution) for each subject, diluting it with eight pints of water. The jar containing the solution was set 4 feet above the level of the body, and connected by a tube with the common carotid artery. The injection takes less than ten minutes to run into the body. The arteries may be injected with plaster of Paris immediately afterwards, and the body is then ready to be sent into the dissecting-room, or kept for after use. The cost per body is a little over three shillings.

Mr ARTHUR KEITH read a short paper on *The Relative Position of the Spinal Accessory Nerve to the Jugular Vein and Transverse Process*

of the Atlas, and on the Connection of this Nerve with Stounds of Pain in certain Movements of the Head. When the head was bent towards the right shoulder, then suddenly raised and rotated towards the left shoulder, many people felt at times a sudden and intense pain shooting downwards and backwards, as if along the right spinal accessory nerve. He suffered from it only on the right side, never on the left. About two out of every five students appeared to suffer from it. This pain, he believed, although he could not remember his authority, was usually ascribed to a nipping of the sub-occipital nerve between the occipital condyle and the articular process of the atlas, but the character of the pain and an examination of the relationships of the sub-occipital nerve rendered this explanation improbable. If an incision be made along the upper part of the anterior border of the sternomastoid on the right side, so that the spinal accessory nerve may be felt with the finger lying on the transverse process of the atlas, if the head be then flexed towards the right side, and at the same time rotated so that the face turns towards the left shoulder, the spinal accessory nerve will be felt to slip towards the extremity of the transverse process of the atlas, and in certain cases to slip over the extremity of the process. If the head be returned to its natural position, the nerve again slips in front of the transverse process; but it could be easily understood how, in sudden movements of the head towards the opposite shoulder, the nerve might be caught and stretched for an instant on the tip of the process, and a stound of pain caused. The anterior tuberosity on the transverse process of the atlas, as already pointed out by Dr Allen (*Journ. Anat. and Physio.*, 1880, vol. xiv. p 18), was variable in size and shape, and had frequently an irregular outline, so that the nerve might be caught as it passed over the tuberosity.

In this connection the relationship of the spinal accessory nerve to the jugular vein must also be taken into consideration. When the nerve escaped from the base of the skull behind the jugular vein, it lay directly on the transverse process; when the nerve escaped between the internal carotid artery and the jugular vein, it was then separated from the transverse process by the internal jugular vein, as by a blood pillow. In this position, it appeared to him, the spinal accessory nerve was less likely to be caught upon the transverse process of the atlas.

In 25 bodies which he had examined he had found the following arrangement:—

In 17 bodies the spinal accessory nerve passed between the carotid artery and jugular vein on both sides. In 5 bodies the nerve passed between the jugular vein and transverse process of the atlas on both sides. In 2 bodies the nerve passed behind the jugular vein on the right side, in front of it on the left. In one body the nerve passed in front of the vein on the right side, behind it on the left.

In these 25 bodies the nerve passed in front of the vein 37 times, behind it 13 times, so that the first arrangement was three times as common as the second. Mr Grimsdale of St George's Hospital, however, had found an equal frequency of each form in the 10 bodies he

had examined. An interesting variation was that which Mr Grimsdale and he had each found once. The spinal accessory nerve escaped in front of the jugular vein, but behind the inferior petrosal sinus, which joined the jugular vein about three centimetres below the jugular foramen. At first sight the nerve appeared to perforate the jugular vein.

The escape of the spinal accessory nerve between the jugular vein and carotid artery was, he believed, peculiar to the human race. It might occur as an uncommon variation in the anthropoids, but hitherto he had not met with an instance; it never occurred amongst the lower primates; in them the nerve lay always behind the vein. The peculiar relation of the spinal accessory to the jugular vein in man seemed capable of a simple explanation. The size of the lateral sinus was in direct relationship to the size of the mantle of the brain; the inferior petrosal sinus had some relationship in size to the development of the basal ganglia, so that, in the lower primates, the inferior petrosal sinus was nearly as large as the lateral sinus, while, in man, the inferior petrosal sinus appeared as a small tributary of the internal jugular vein. When the continuation of the lateral sinus and the inferior petrosal sinus are nearly equal in size, they advance towards each other to form the jugular vein on the *outer* side of the internal carotid artery, and the nerve naturally escapes behind the vein. In man, however, where the lateral sinus has become the dominant blood channel, and the inferior petrosal sinus a small and unimportant tributary, the jugular vein comes to lie naturally behind the carotid artery, so that the nerve's nearest route lies in escaping between the artery and the vein. The peculiar course of the spinal accessory in man was perhaps also due in part to the highly developed cervical curve of his vertebral column.

The peculiar and variable relationship of the spinal accessory nerve to the jugular vein and transverse process of the atlas in man he looked upon as resulting, in the first place, from the large development of his brain mantle; and in the second place, from an imperfect adaptation to the upright posture.

Mr ARTHUR KEITH exhibited *Specimens and Diagrams, showing a Fibrous Band lying on the Dorsum of the Scapula superficial to the fascia covering the infraspinatus*. It took its origin from the inferior angle of the scapula between the attachments of the *rhomboideus major* and *teres major* muscles, and spread upwards, lying on the infraspinatus fascia, to become attached to the base of the spine of the scapula, under the origin of the deltoid muscle. Out of 24 human bodies, at different stages of life, he had found this band very distinctly marked in 12, only partially present in 4, while it was absent in the remaining 8. He had observed it well marked in an orang and in a specimen of *Macacus silenus*, but in fourteen other specimens of *Primates* he had examined specially for this band he had found it absent.

His colleague, Dr Sequeira, had pointed this band out to him, but in spite of much inquiry they had failed to come to any satisfactory

conclusion as to its nature. In the human foetus it was seen in some cases to be continuous at its origin with the teres major, in others with the rhomboid, in others with fibres from the latissimus dorsi, and frequently it had no connection with any of these muscles. The occasional connection of this band with the latissimus dorsi, teres major and rhomboid was suggestive of its being part of the embryonic sheet out of which the deltoid, trapezius and these three muscles were developed. It appeared to fill up in part the rhomboidal blank in this primitive muscular sheet on the dorsum of the scapula—the interval between the rhomboideus major, teres major and latissimus dorsi below; the trapezius and deltoid above. In an ornithorynchus which Professor Stewart had permitted him to examine, he found a muscle in a position somewhat similar to this band. The muscle belonged to the panniculus layer, and arose over the lumbar and inguinal regions, and was inserted into the base of the spine of the scapula, superficial to the deltoid. This band was always beneath the deltoid, and never became continuous with it. It was of some interest to observe that of the 24 bodies he had examined for an infra-scapular band, in 2 the deltoid had an additional origin (costo-deltoides) from the axillary border of the scapula above the origin of the teres major, and in both of these the fibrous band was present; in two others the deltoid had a partial origin (basio-deltoides) from the vertebral border of the scapula, but in neither of these was a band present; in 5 bodies the deltoid had additional fibres arising over the infrapinatus muscle, but in only one of these was there a well marked band; in the remaining 15 bodies the deltoid had its normal origin, and in 9 of these the fibrous band was well marked. The extra origins of the deltoid occur with greater frequency in anthropoids than in man, especially amongst chimpanzees, but apparently this fibrous band does not occur so often. He brought forward these additional facts concerning the origin of the deltoid, because at first he had been inclined to regard this band as representing the basilar origin of the deltoid.

Mr HERTSLET (introduced by Mr KEITH) read a paper on the *Comparison of two Specimens*—(1) Rudimentary Ribs on the 7th Vertebra; (2) Rudimentary Ribs on the 8th Vertebra. This paper, with notes on the literature of the subject by Mr Keith, will be found on p. 562 of the *Journal of Anatomy*, July 1896.

Professor WARDROP GRIFFITH showed a *Larynx from a Male Subject which presented a Diverticulum*. This started from the interior of the upper segment of the larynx on the right side, about midway between the tip of the arytenoid cartilage and that of the epiglottis, and midway between the ary-epiglottic fold and the margin of the cartilage of the epiglottis. It was three-quarters of an inch above the false cord, and slightly above the level of the cushion of the epiglottis.

Its depth was about half an inch, and it would admit an ordinary sized pencil.

Its mucous membrane did not present any appearance of disease, and resembled that of the adjoining part of the larynx. The sac was found to lie beneath the thyro-hyoid muscle, and to reach almost to its posterior margin, terminating in a blunt extremity close to the tip of the great cornu of the hyoid bone.

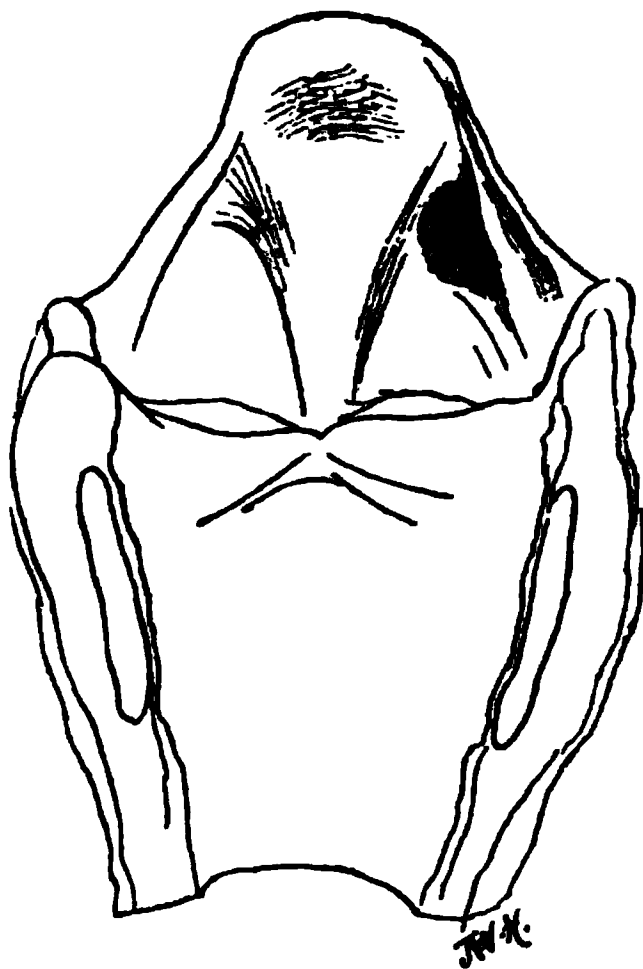


FIG. 1.

It was partially invested by, and partially passed through, the thyro-hyoid membrane, which was difficult to dissect on both sides, and beneath which the amount of fat was considerable.

The superior laryngeal nerve passed mainly below it, but one branch was traced upwards behind, and internal to it, to the mucous membrane.

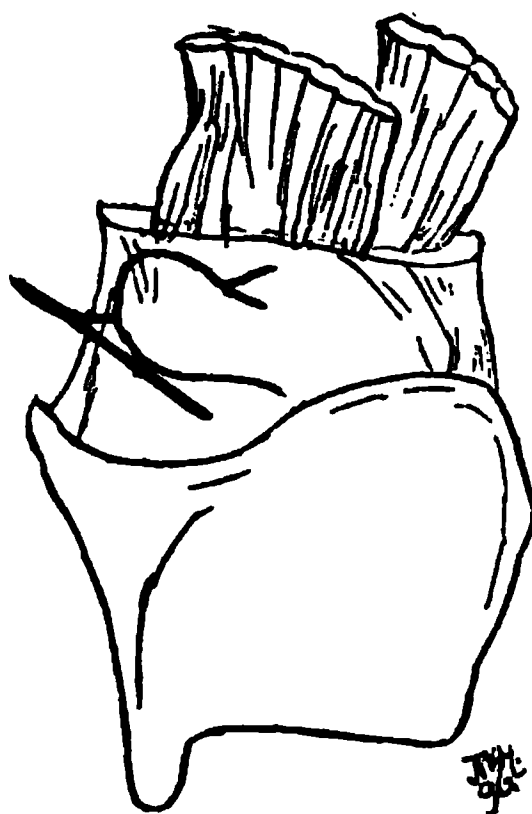


FIG. 2.

The diverticulum in this case was quite unconnected with the laryngeal pouch, and so no homology could be traced with the diverticula of certain mammals. It was unconnected with the pharynx, and could not represent a persistent branchial cleft.

At the position in the larynx from which it arose there was always a concavity between the ary-epiglottic fold and the margin of the cartilage of the epiglottis, and this part of the laryngeal wall was normally very thin, and actually translucent when the thyro-hyoid muscle was dissected away. It was thought that this depression was more marked than usual on the left side of the specimen.

Notwithstanding the natural thinness of the wall of the larynx here, it was difficult to account for the diverticulum on pathological grounds, for the expulsive efforts of coughing would exercise little pressure on the mucous membrane *above* the rima glottidis.

In the discussion which followed the exhibition of this specimen, Prof. HOWES and Dr KERTH agreed that the diverticulum had no morphological significance. Professor CURNOW regarded it as being caused by a retention cyst.

Professor WARDROP GRIFFITH exhibited two cases of *Fusion of the Occipital Bone and Atlas*. The following is an account of the specimens:—

CASE 1. Specimen taken from body of a tall man, in whom during life it was noticed that power of nodding was absent.

Specimen was shown at Anatomical Society meeting in Leeds in 1889.

Blending at articular surfaces, and at the posterior part of arch.

(a) At articular surfaces one can see the line of union, especially on the left side. From behind, one can see a lamina of cartilage separating the bones.

(b) The posterior blending is about 1 inch in extent.

The atlas is a well developed one in every way; there is no shortening of the bones from above downwards. There is some redundancy of bone about the trapezius ridges and post. part of arch of atlas.

CASE 2. The atlas shows signs of imperfect development. The arch is not complete behind, there being a deficiency of $\frac{1}{8}$ ". The posterior arch on each side is very ill developed, and is fused with the occipital bone in its whole extent, except where a small gap is left in front for passage of sub-occipital nerve and vertebral artery. The line of fusion can be readily seen on the right side, but on the left side there is hardly any indication.

The outer opening of the posterior condyloid foramen is $\frac{1}{8}$ " - $\frac{1}{6}$ " above and in front of the lateral gap on the right side, and separated from it by a bar of occipital bone. On the left side the aperture is in the upper wall of the lateral gap, and is manifestly continuous with a small canal formed behind by a partial union of atlas and occipital bone.

On each side the transverse processes are small, short, and of light

build. On the right side the anterior part is wanting, but the posterior is more substantial.

The lateral masses are continuous with the occipital condyles, and this, both as regards extent and degree, is greater on the left than on the right side. On the left side the fusion reaches to $\frac{1}{8}$ " from the middle line, and on the right to $\frac{1}{4}$ ". The mesial gap is thus small, viz., $\frac{1}{8}$ in. in width, and $\frac{1}{8}$ in height.

Faint indication of line of junction can be made out at upper part of lateral mass on left side, and much more readily on the right side, where some of the upper aspect of the articular surface of the atlas can be seen. The anterior condyloid foramen is $\frac{1}{8}$ " above this line of fusion on the right side, but on the left side it is quite close to the atlas.

The fusion is thus everywhere more continuous on the left than on the right side, and, with the exception of the transverse process, the development is less on the left side.

The inferior articular surfaces of the atlas are flattened and large.

Table of Measurements of Cases of Fusion of Occipital Bone with Atlas.

	CASE I.	CASE II.
Anterior aperture—		
Width,	$\frac{6}{16}$ "	$\frac{1}{8}$ "
Height,	$\frac{1}{8}$ "	$\frac{1}{8}$ "
Lateral aperture for passage of sub-occipital nerve and vertebral artery—		
Right { Width,	$\frac{4}{16}$ "	Size of
Height,	$\frac{1}{8}$ "	Goose Quill.
Left { Width,	$\frac{4}{16}$ "	Size of
Height,	$\frac{1}{8}$ "	Crow Quill.
From lower margin of anterior condyloid foramen to centre of inferior articular surface of atlas—		
Right,	$\frac{10}{16}$ "	$\frac{7}{8}$ "
Left,	$\frac{9}{16}$ "	$\frac{5}{8}$ "
From transverse processes of atlas to portion of occipital bone above—		
Right,	$\frac{5}{16}$ "	$\frac{1}{4}$ "
Left,	$\frac{1}{4}$ "	$\frac{1}{4}$ "
From line of fusion of articular surfaces to margin of ant. condyloid foramen—		
Right,	$\frac{2}{16}$ "	$\frac{3}{16}$ "
Left,	$\frac{1}{16}$ "	$\frac{1}{16}$ "
From lateral gap to posterior condyloid foramen—		
Right,	$\frac{7}{16}$ "	$\frac{1}{4}$ "
Left,	$\frac{6}{16}$ "	$\frac{1}{8}$ "

The prominence of bone just above the anterior condyloid foramen inside the skull is very large and sharp, especially on the left side. No bony redundancy elsewhere.

Cervical vertebræ are rather redundant, with spongy-looking surfaces. Post. part of 2nd left transverse process very small.

In contrasting the two examples, Dr Griffith pointed to the imperfect development of the atlas and its more complete amalgamation in Case 2, as indicating that the fusion took place at a much earlier date than in Case 1, in which the atlas may have existed for years after birth as a separate bone. This specimen also presented signs of disease.

Professor STRUTHERS had, in 1874, described an example with which in many particulars Dr Griffith's second case agreed.

Dr L. FRYBERGER gave the following account of a specimen of *Malformed Heart and great Vessels* he exhibited:—A boy, 11 months old, of slightly rickety habitus, was admitted to the Great Northern Central Hospital, suffering from meningitis. At the post-mortem examination a few days later the following interesting malformations were found:—

On opening the thorax, the lungs were found perfectly inflated, and touching the midsternal line with their anterior edges. There appeared to be no left innominate vein; a thin vein, which was in its stead, was accidentally removed with the manubrium sterni. On the right side there was a perfectly normal descending vena cava, the vena azygos arching forwards above the root of the right lung, and entering the descending cava opposite the upper border of the 5th rib; on the left side a left descending vena cava was seen running down in front of the root of the left lung, and turning to the back of the heart, where it entered the coronary sinus. It appeared to be the continuation of the left internal jugular vein, was of the same width as the vein on the right side, and received near the inner end of the left clavicle the left subclavian veins; also a left vena azygos, which in a similar way to the right azygos arched forwards above the root of the left lung, and entered the left descending cava at the level of the 5th rib. The left azygos vein was twice as big as its fellow on the right side, and received the same number of branches as the azygos proper.

The coronary sinus is very wide, and covers the whole of the posterior wall of the left auricle; the opening of the coronary sinus measured $\frac{1}{2}$ in. diam.

The heart is at a right angle to the spinal axis; its anterior aspect is almost entirely formed by the right auricle and right ventricle; only a narrow strip of the left ventricle could be seen lining the left border of the right ventricle. The left auricular process appears as a small tongue-shaped appendix between the left descending cava and the pulmonary artery.

The right auricle, $\frac{3}{4}$ in. \times 1 in., is much dilated; its auricular process overlies the insertion of the aorta in front. The left auricle can only be brought to right by making an incision through the anterior

wall of the coronary sinus; it is only half the size of the right auricle. The muscular wall of the right auricle is more than twice as thick as that of the left. The foramen ovale presents in its upper half an elliptic opening the size of a rice-corn.

The right ventricle has a conical shape, is $1\frac{1}{2}$ in. long by $\frac{2}{3}$ in. wide, the ventricular wall from $\frac{1}{8}$ - $\frac{1}{4}$ in. thick. The tricuspid valve of normal shape; its cusps have sharp free edges; the auricular surface of the valve is perfectly smooth; the atrio-ventricular orifice measures $\frac{1}{2}$ in. across. To the left of the posterior cusp is a hole $\frac{3}{8}$ in. by $\frac{1}{4}$ in. between this cusp and the ventricular septum which leads straight upwards into the aorta.

The pulmonary artery lies to the left and somewhat behind the aorta, has very thin walls, and measures at the valvular end $\frac{1}{4}$ in. across. The ostium pulmonale is very narrow ($\frac{1}{8}$ in.). Two rather fleshy lip-shaped valves shut the vessel off the right ventricle. The funnel-shaped portion of the right ventricle, which leads upwards to the pulmonary orifice, is very narrow and very steep.

The membranous part of the interventricular septum is absent; the defect thus caused in the septum measures $\frac{1}{3}$ in. \times $\frac{1}{4}$ in., is of elliptic shape, with smooth, rounded-off edges.

The left ventricle is small, its walls thin; the mitral orifice measures $\frac{1}{3}$ in. across; the free edges and auricular surface of the mitral cusps perfectly natural.

The aorta is $\frac{1}{2}$ in. wide, has 3 well-developed semilunar valves; it is so inserted that its orifice would be divided into two nearly equal halves by an ideal section carried through the muscular septum.

The ductus arteriosus is patent throughout, and admits a probe $\frac{1}{8}$ in. thick without difficulty.

A single posterior bronchial artery, $\frac{1}{10}$ in. wide, transmits aortic blood to both bronchi.

The pulmonary veins and the ascending vena cava are perfectly normal.

The aorta evidently had at all times contained mixed blood; the lungs must have been supplied with a sufficient quantity of blood, as they were not undergrown; the arterial pulmonary circulation has taken place through the stenosed pulmonary orifice, the ductus arteriosus Botalli, and probably through wide anastomoses of the end ramifications of the bronchial arteries with those of the pulmonary artery.

At no time during life was cyanosis noted; there was no clubbing of the end phalanges of fingers or toes, and no periosteal formative changes on the tibiae.

A soft systolic bruit was heard loudest over the pulmonary area, and attributed to a slight pulmonary stenosis.

Professor JOHNSON SYMINGTON read a paper on *Genu Valgum Adolescentium*, which will be published at a later date.

Professor JOHNSON SYMINGTON gave a lantern demonstration on *Sections of the brain of the Echidna*.

Professor C. S. SHERRINGTON gave a lantern demonstration on the *Cutaneous Distribution of Spinal Nerves*. He exhibited a large number of photographic slides of *Macacus rhesus*, showing the anæsthetic areas after section of the various spinal nerves.

Professor A. M. PATERSON read a paper on *Some Points in the Distribution of the Spinal Nerves*. He divided his communication into two parts, dealing first with the homologies of the limb nerves. The question which he set himself to answer was—"Are the limb nerves homologous with the lateral branches, or with the entire anterior divisions of the thoracic nerves?" He inclined to the latter view, and stated the following points in its favour:—(1) The absence of anterior cutaneous nerves to the trunk in the limb regions. (2) The division of the nerves entering the limb plexuses into posterior and anterior divisions, comparable to the lateral and anterior branches of a thoracic nerve. The main objections to the view, on the other hand, were—(1) The apparent anomalies in the arrangement of the limb nerves. (2) The presence of an intercostal branch to the first thoracic. (3) The behaviour of the second thoracic and third sacral nerves.

Professor Paterson stated his opinion that the dorsal branch of the first thoracic was contained in the dorsal branch of the ulnar and the posterior branch of the internal cutaneous nerves, while in the leg the dorsal branch of the third sacral was contained in the external saphenous and small sciatic.

The second part of the paper was devoted to the segmental distribution of the limb nerves. With regard to the muscles, the following laws were found to apply:—(1) No limb muscle proper receives its nerve supply from the posterior primary divisions. (2) The limb muscles are fundamentally divisible into dorsal and ventral strata, supplied by dorsal and ventral nerves of the plexuses; and dorsal muscles and ventral muscles are always supplied by their corresponding nerves. A double nerve supply only occurs at the borders of the limb, *i.e.* pectineus, biceps, brachialis anticus, and indicates a fusion of dorsal and ventral elements. (3) The muscular stratum is more extensive on the ventral than the dorsal surface of each limb, and the ventral nerves are more numerous. The nerve added is postaxially placed.

Considering all the evidence, Professor Paterson discarded Herringham's axioms "that the muscles nearer the axis of the limb and the muscles nearer the surface are supplied by higher nerves"; but allowed a basis of truth to the same author's law which says—"Of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve, and that near the tail end by the lower nerve."

After considering the segmental distribution of the cutaneous nerves, the following points of resemblance and difference between them and the nerves to the muscles were noticed.

(a) *Resemblances*.—(1) Dorsal and ventral surfaces are supplied by dorsal and ventral nerves. (2) The preaxial and postaxial nerves

are shed along the borders of the limbs in their passage towards the periphery, the central nerves extending furthest. (3) The preaxial nerves tend to disappear more proximally than the postaxial nerves.

(b) *Differences*.—(1) The dorsal cutaneous area is much more extensive than the ventral area. (2) The dorsal area is supplied by more numerous nerves, and the added nerves are generally more postaxial. (3) Nerves not properly limb nerves are brought into requisition for the supply of the skin; this is especially seen at the borders of the limbs.

Professor Paterson's paper will be found in *extenso* on p. 530 of the *Journal of Anatomy*, vol. xxx.

Fig. 1.

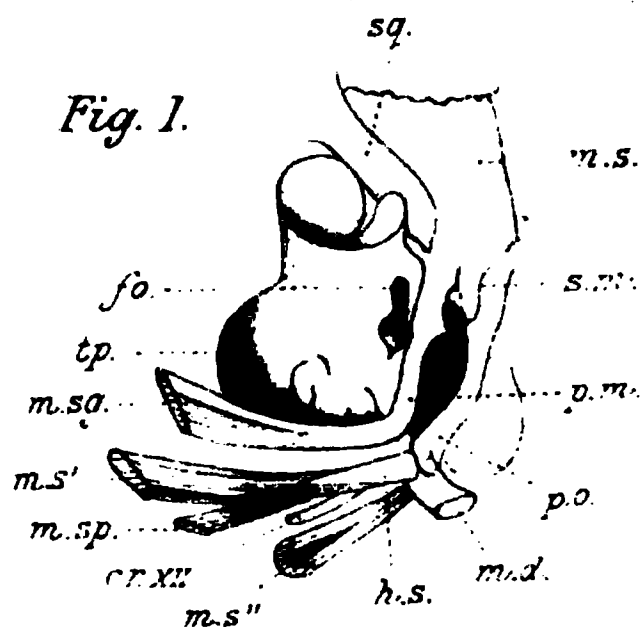


Fig. 2.

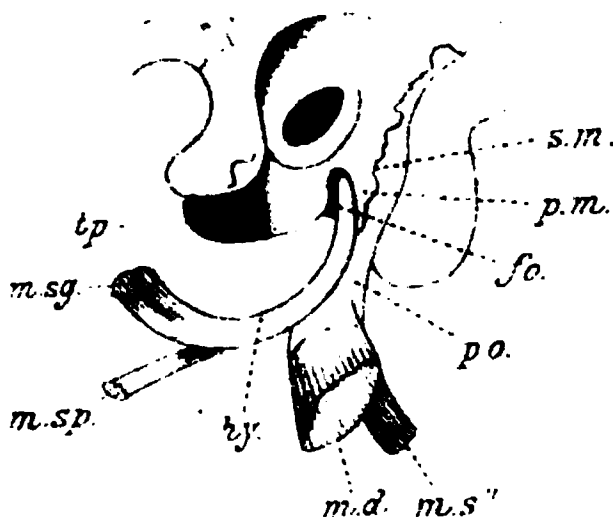


Fig. 3.

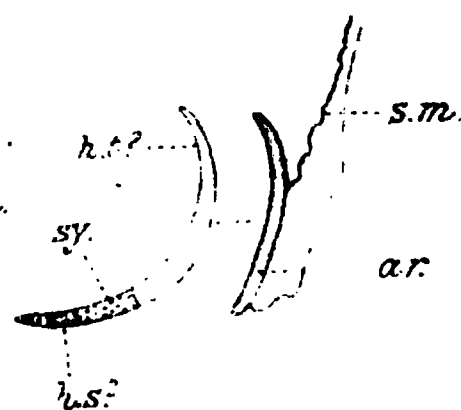


Fig. 4.

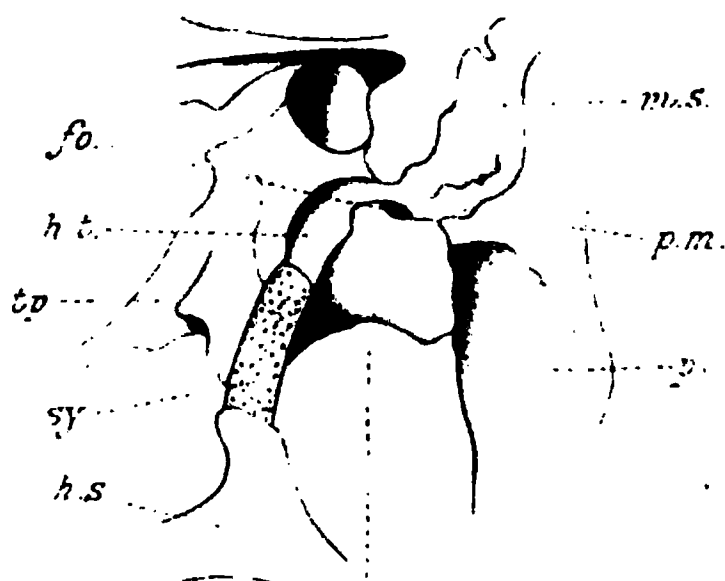


Fig. 6.

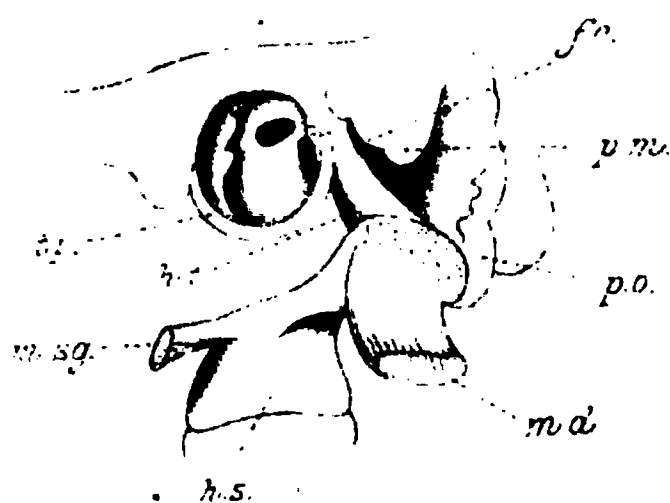


Fig. 5.



Fig. 7.

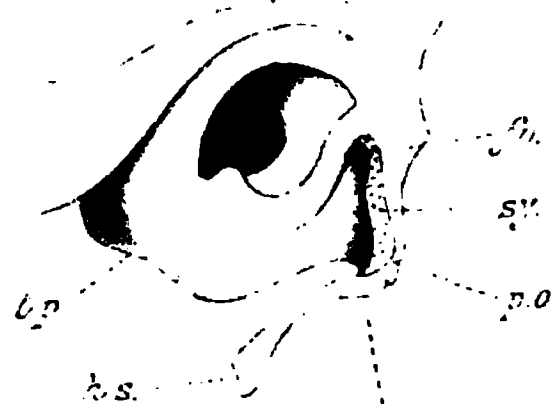


Fig. 9.

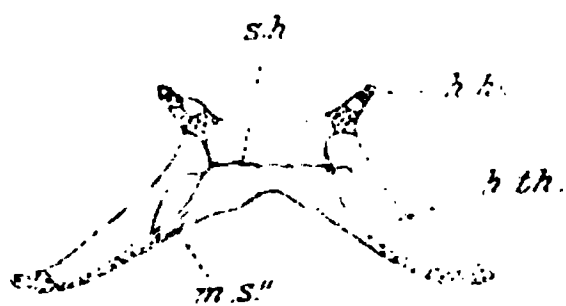
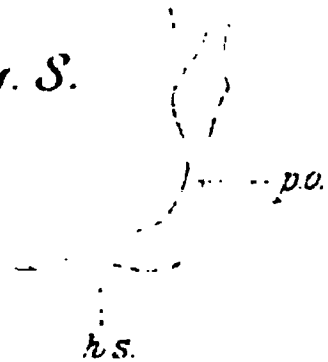


Fig. 10.



Fig. 8.



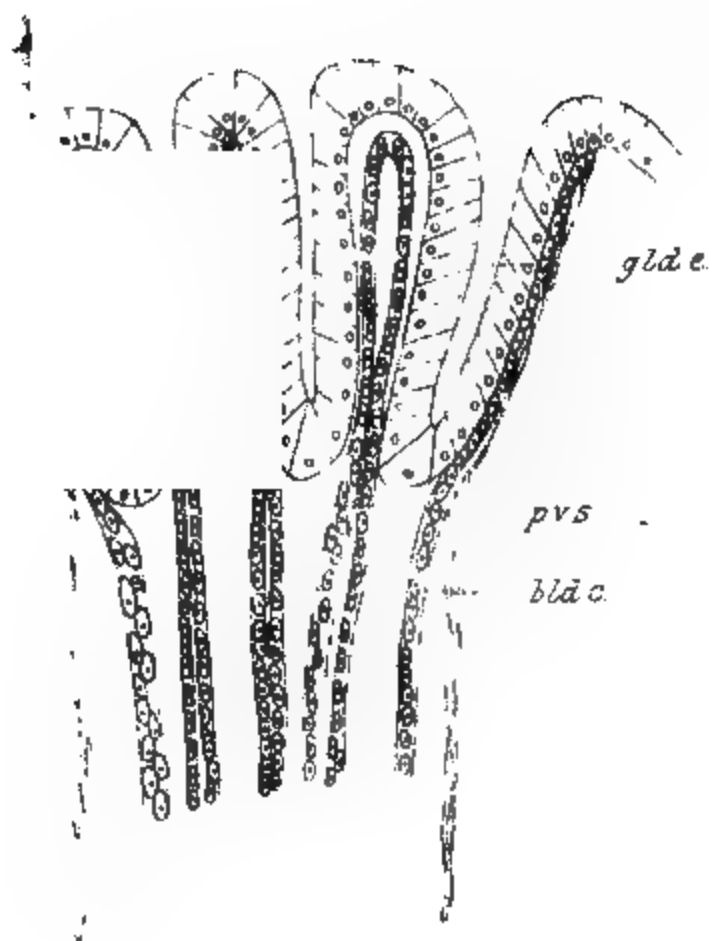


Fig. 5.

